SEISMIC DESIGN OF MULTI-STOREYED BUILDING USING WATER TANK AS A TUNED MASS DAMPER

A MAJOR PROJECT-II REPORT

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE AWARD OF DEGREE
OF

MASTER OF TECHNOLOGY

In

STRUCTURAL ENGINEERING

SUBMITTED BY

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2K18/STE/10

UNDER THE SUPERVISION OF

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DEPARTMENT OF CIVIL ENGINEERING
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OCTOBER, 2020

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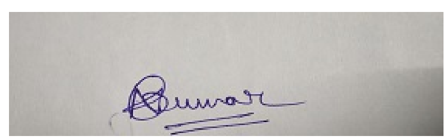
CANDIDATE'S DECLARATION

I, **Neeraj Kumar** Roll No. **2K18/STE/10** student of M. Tech. (Structural Engineering), hereby declare that the Major Project-II Dissertation titled "**Seismic Design Of Multi-Storeyed Building Using Water Tank as a Tuned Mass Damper"** which is submitted by us to the Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma Associate ship, Fellowship or other similar title or recognition.



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CERTIFICATE

I hereby certify that the Project Dissertation titled "**Seismic Design Of Multi-Storeyed Building Using Water Tank as a Tuned Mass Damper"** which is submitted by Mr. Neeraj Kumar, Roll No. 2K18/STE/10 Department of Civil Engineering, Delhi Technological University, Delhi in partial fulfilment of the requirement for the award of the degree of Master of Technology, is a record of the Major project-II work carried out by these students under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

23.X.2020

Place: Delhi

Date:

(ASSOCIATE PROF. G.P AWADHIYA)

SUPERVISOR

ACKNOWLEDGEMENT

It gives us immense pleasure in expressing our gratitude to all those people who supported us and have had their contribution in making this Major project-II possible. We would like to express our sincere gratitude well towards our HOD who gives us the providential opportunity to execute this project on the topic of "**Seismic Design Of Multi-Storeyed Building Using Water Tank as a Tuned Mass Damper**".

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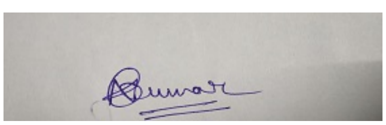
The completion of this project could not have been accomplished without the support of our teammates and family to use our maximum time and gratitude to complete this project.

SUBMITTED BY



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ABSTRACT

Present Evolution in the construction sector need larger and lighter structures, That are often more versatile & have a fairly low damping rate. That raises the chances for failure and even difficulties in terms of serviceability. There are currently many techniques Accessible to mitigate the structure's Vibration, the method of using TLD is a newer one out of the many techniques used for vibration management. The weakness of structures with & without liquid damper tuned within different load conditions is analysed and seismic field through various water depths is examined for the study. Research is performed for different heights to test the structure's seismic activity with & without modified liquid damper building is examined for distinct heights to see what changes will occur if both structural systems vary in height. Characteristics of the seismic behaviour of both structural structures therefore suggest supplementary measures to direct the design and layout of these structures in seismic regions and also to enhance the seismic loading efficiency of these structural systems.

In the Current study, a G+4, G+10, G+14, G+18 And G+22 storied building was analyzed through the Time history analysis using ETABS 2018 Software.

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CHAPTER 1

INTRODUCTION

Structures in civil engineering are situated in environments where strong wind forces or earthquakes are ordinary, during their lifetime they will be subject to severe vibrations. This can vary from harmless to serious vibrations, resulting in severe damage to the structure and probable structural collapse. Civil engineering is continually finding ways of overcoming this underlying phenomenon. Conventional structures enhancement approaches use more resources and energy. In addition , low masses cause higher seismic powers. In reducing the seismic and other dynamic effects on civil engineering structures, alternative strategies such as passive control systems are found to be successful. The high-rise or medium-rise number buildings and low-rise buildings that exist in the world today. That structures have Low damping of natural matter, for the most part. A structural device's damping ability are increasing, or consideration of the need for other mechanical means to improve damping potential of the building, it has grown to be more popular in the new generation of high and super-high buildings. High rise building of the new generation is fitted with an artificial damping system to regulate vibration by energy dissipation. The different methods of vibration control include the passive, active , semi-active, hybrid. The TMD theory of the vibrations of tall buildings and other civil engineering structures has now been applied. A Tuned Mass Damper (TMD) is a passive damping mechanism that typically uses a secondary mass connected through the spring to a main structure & dashpot to minimise the structure's dynamic response. The secondary mass system is designed to have the natural frequency adjusted to that of the primary structure, depending on its mass and rigidity. Common man is unable to afford these control systems, since they tend to be inefficient. Therefore plans are to be made to use the current building portion to which the earthquake and wind induced vibrations in the building. Since the water storage tanks are built-in building components and most of them are built on the top level of the roof, they add dead burden to the structure. This extra mass may be used as a damper during earthquakes to take over the surplus energy transmitted to the structure.

CHAPTER 2

LITERATURE REVIEW

A. General

TMD has proved to be effective in reducing seismic response among the various seismic response control devices. Passive TMD may be framework, attached to the main framework by means of springs, and the TMD parameter is matched to that of the main structure such that the main structure's dynamic response during the Earthquake is reduced. Rather than linking a separate element to the principal structure, It is beneficial to use the water tank as a passive TMD which forms an integral part of the structure. Research is ongoing on the use of water tank as passive TMD and some papers are presented in which findings show a reduction in seismic response.

B. Critical Appraisal of Literature

The optimum parameters of the Tuned Mass Damper (TMD) resulting in a substantial reduction of the seismic loading response of the structures are presented. The criteria used to obtain parameters is to choose the frequency (tuning) and damping ratios for a given mass ratio that would result in the first two modes of vibration having equal and significant modal damping effects.. The parameters are used to measure the response of multiple single and multi-degree freedom structures with TMDs to various excitations from earthquakes. Results show that the use of the proposed parameters greatly decreases the displacement and acceleration. Using the so-called "super sub-structure configuration," the system can also be used in vibration management of large buildings‟,Where substructures act as principal structure vibration absorbers. It is shown that substantial reduction in the response of tall buildings can be achieved by choosing the optimum TMD parameters as proposed in this paper. The corresponding damping ratios in the first two modes were found to be greater than the average damping ratios of the lightly damped structure and the heavily damped TMD.

Properly designed tuned-mass control systems can be characterized as follows:

- They reduce seismically induced reactions in terms of accelerations, displacements, internal strains and stresses as well as subsoil demands.

- They increase the structural safety. The collapse of a building becomes less probable and hence, human life is protected.

- They make structures more serviceable. Damage and corresponding repair costs are reduced significantly in the event of seismic events.

- Compared to conventional methods of reinforcement, the building can usually be in operation during the TMCS installation (if no further measures are required).

- With regard to the overall procedure and the material required to install a tuned mass system this strategy can be classified as 'cost effective'.

OBJECTIVE

1. To analyse the behaviour of structure with and without dampers by Time history analysis.

2. To analyse the performance of tuned liquid dampers with several depths of water tank and with different stories.

CHAPTER 3
METHODOLOGY

A. Vibration Absorber Or Tuned Mass Damper

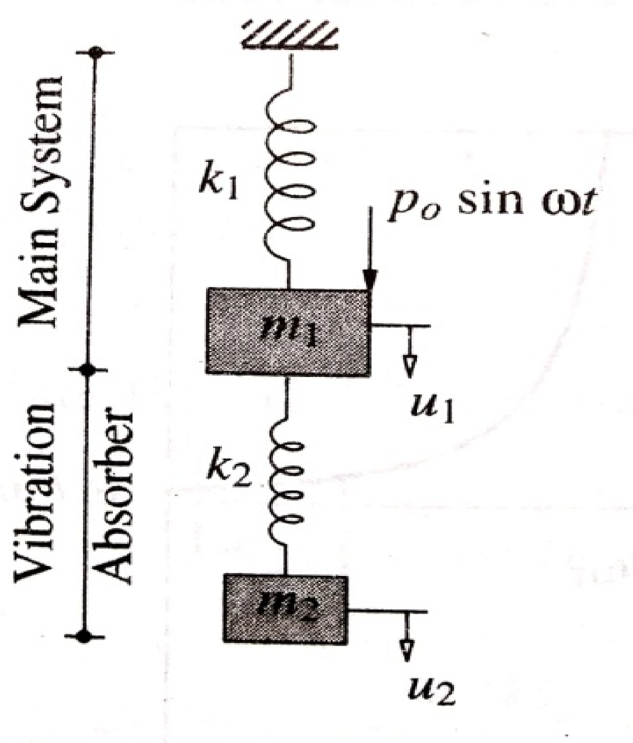


Figure 1: Problem Figure

$m1\ddot{u}1 + k1u1 - k2u2 + k2u1 = P0\ \sin \omega t$

$$m1\ddot{u}1 + (k1 + k2)u1 - k2u2 = P0\ \sin \omega t$$

$$m2\ddot{u}2\ - k2u1 + k2u2 = 0$$

$\begin{bmatrix} m1 & 0 \\ 0 & m2 \end{bmatrix} \begin{bmatrix} \ddot{u}1 \\ \ddot{u}2 \end{bmatrix} + \begin{bmatrix} k1 + k2 & -k2 \\ -k2 & k2 \end{bmatrix} \begin{bmatrix} u1 \\ u2 \end{bmatrix} = \begin{bmatrix} \mathrm{P0\ \ sin\ \omega t} \\ 0 \end{bmatrix}$

A direct solution we can attempt-

Assume;

$\begin{bmatrix} u1 \\ u2 \end{bmatrix} = \begin{bmatrix} A1 \\ A2 \end{bmatrix} \sin \omega t$

$\begin{bmatrix} \dot{u}1 \\ \dot{u}2 \end{bmatrix} = \begin{bmatrix} A1\omega \\ A2\omega \end{bmatrix} \cos \omega t$

$$\begin{bmatrix} \ddot{u}1 \\ \ddot{u}2 \end{bmatrix} = \begin{bmatrix} -A1\ \omega^2 \\ -A2\ \omega^2 \end{bmatrix} \cos \omega t$$

$$\begin{bmatrix} k1 + k2 - m1\omega^2 & -k2 \\ -k2 & k2 - m2\omega^2 \end{bmatrix} \begin{bmatrix} A1 \\ A2 \end{bmatrix} = \begin{bmatrix} P0 \\ 0 \end{bmatrix}$$

$$[[K] - \omega^2[M]] \begin{bmatrix} A1 \\ A2 \end{bmatrix} = \begin{bmatrix} P0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} A1 \\ A2 \end{bmatrix} = \left[[K] - \omega^2[M]\right]^{-1} \begin{bmatrix} P0 \\ 0 \end{bmatrix}$$

$$= \frac{Adj\ [[K]-\omega^2\ [mI]]}{|[K-\omega^2\ [mI]} \begin{bmatrix} P0 \\ 0 \end{bmatrix}$$

$[k] - \omega^2[m] = [0]$ We can use to determine natural frequencies say it leads to frequency $\omega1, \omega2$

$$\begin{bmatrix} k1 + k2 - m1\omega^2 & -k2 \\ -k2 & k2 - m2\omega^2 \end{bmatrix} = [0]$$

$$(k1 + k2 - m1\omega^2)(k2 - m2\omega^2) - k2^2 = 0$$

$$(k1 + k2)k2 - (k1 + k2)m2\omega^2 - k2m1\omega^2 + m1m2\omega^4 - k2^2 = 0$$

$$m1m2\lambda^2 - \{(k1 + k2)m2 + k2m1\}\lambda + \mathrm{k1k2} = 0 \qquad \text{(A)}$$

$$\lambda = \frac{\{(\mathrm{k1 + k2)m2 + k2m1}\} \pm \sqrt{\{(k1 + k2)m2 + k2m1\}^2 - 4k1k2}}{2\mathrm{m1m2}}$$

$$\lambda 1{,}2 = \frac{\{(\mathrm{k1 + k2)m2 + k2m1}\}}{2\mathrm{m1m2}} \pm \frac{\sqrt{\{(k1 + k2)m2 + k2m1\}^2 - 4k1k2}}{2\mathrm{m1m2}}$$

So, this expression (A) can be expressed as :

$$m1m2(\lambda - \lambda 1)(\lambda - \lambda 2) = 0$$

$$m1m2(\omega^2 - \omega 1^2)(\omega^2 - \omega 2^2) = 0$$

$$|k - \omega^2 m| = \mathrm{m1m2}(\omega^2 - \omega 1^2)(\omega^2 - \omega 2^2)$$

$$\begin{bmatrix} A1 \\ A2 \end{bmatrix} = \frac{1}{|K-\omega^2 m|} \begin{bmatrix} k2 - m2\omega^2 & k2 \\ k2 & k1 + k2 - m1\omega^2 \end{bmatrix} \begin{bmatrix} P0 \\ 0 \end{bmatrix}$$

$$\mathrm{A1} = \frac{(k2-m2\omega^2)P0}{m1m2(\omega^2-\omega 1^2)(\omega^2-\omega 2^2)} = \frac{(k2-m2\omega^2)P0}{m1\omega 1^2 m2\omega 2^2 (1-\left(\frac{\omega}{\omega 1}\right)^2)(1-\left(\frac{\omega}{\omega 2}\right)^2)}$$

$$\mathrm{A2} = \frac{\left(\frac{k2}{k1k2} - \frac{m2\omega^2}{k1k2}\right)P0}{(1-\left(\frac{\omega}{\omega 1}\right)^2)(1-\left(\frac{\omega}{\omega 2}\right)^2)}$$

<u>One Specific Problem</u>:

If m1, m2, k1 & k2 are known, we can plot frequency response curve.

i.e. $\frac{A1}{P0/k}$ vs $\frac{\omega}{\omega 1}$ and $\frac{A2}{P0/k}$ vs $\frac{\omega}{\omega 1}$

say k1=2k ;   k2=k   m1=2m   m2=m

$\omega 1 = \sqrt{\frac{k}{2m}}$: $\omega 2 = \sqrt{\frac{2k}{m}}$

so we get

$$\frac{A1}{\frac{P0}{2k}} = \frac{1-\frac{1}{2}(\frac{\omega}{\omega 1})^2}{[1-(\frac{\omega}{\omega 1})^2][1-(\frac{\omega}{\omega 2})^2]}$$

$\frac{A1}{P0/k}$ vs $\frac{\omega}{\omega 1}$

$\frac{A2}{P0/k}$ vs $\frac{\omega}{\omega 1}$

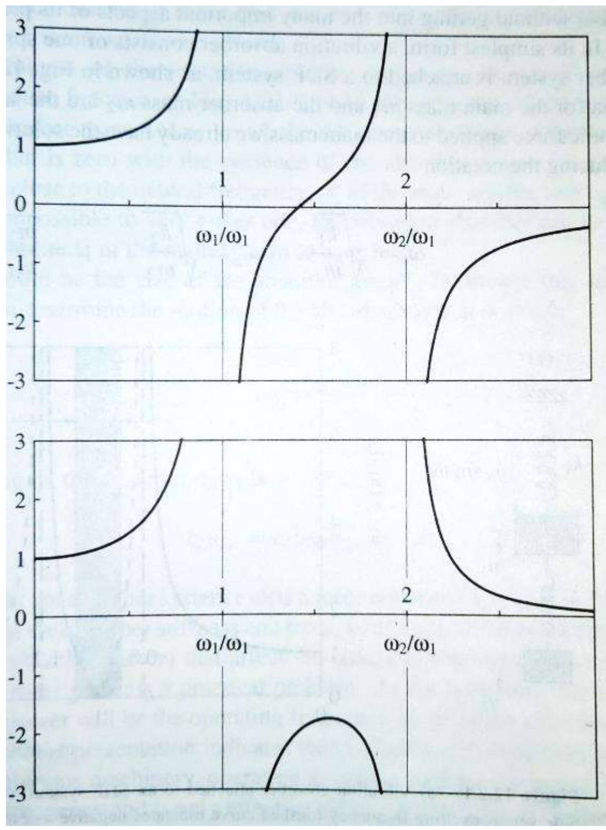


Figure 2: Frequency Response Curve

Now let's do the tuning of mass m2 and its stiffness k2, so that the amplitude of mass m1 comes under control. Then the system k2 and mass m2 are defined as vibration abrosrber.

Say we keep $\mu = 0.2$ and $\omega 1^* = \omega 2^*$

i.e. $\frac{k1}{m2} = \frac{k2}{m2}$ Say so $\frac{k2}{k1} = \mu = \frac{m2}{m1}$

Then we find that,

$$\frac{A1}{P0/k1} = \frac{[1-(\frac{\omega}{\omega 2^*})^2]}{\left[1+\mu\left(\frac{\omega 2^*}{\omega 1^*}\right)^2-\left(\frac{\omega}{\omega 1^*}\right)^2\right]\left[1-\left(\frac{\omega}{\omega 1^*}\right)^2\right]-\mu\left(\frac{\omega 2^*}{\omega 1^*}\right)^2}$$

So,

$$\frac{A1}{(P0/K1)} = \frac{[1-\left(\frac{\omega}{\omega 1^*}\right)^2]}{\left[1+\mu\left(\frac{\omega}{\omega 1^*}\right)^2\right]\left[1-\left(\frac{\omega}{\omega 1^*}\right)^2\right]-\mu}$$

$$\frac{\omega}{\omega 1^*} = \left|\frac{A1}{PO/k1}\right|$$

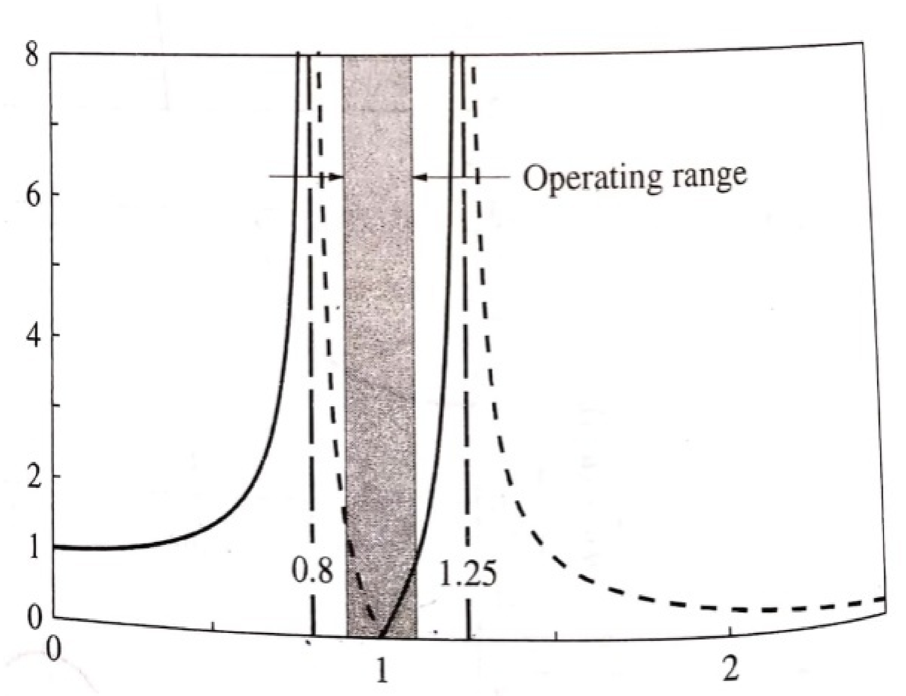
$0.80108 \sim 0.8 = \frac{1-.80108^2}{[1+0.2-.80008^2][1-.80108^2]-0.2} = \sim$

0.92286	1.0
1.0	0
1.09545	1.0
1.25	~

<u>Comments</u> :

1. The system has 2 Degree of Freedom, hence when $\frac{\omega}{\omega 1^*}$ = 0.8 or 1.25 the displacement of m1 goes unbounded.
2. For given $\mu \& \frac{K2}{K1}$ we find that there exists a frequency range in which if the main mass is excited, the amplitude of main mass remains equal to or below the static displacement of $\frac{P0}{K1}$.
3. When $\omega = \omega 1^*$, the displacement of mass m1 ceases exactly this is what we intend to achieve , so mass m2 acts a s an absorber.

4. Plot of $\left|\frac{A1}{P0/K}\right|vs\frac{\omega}{\omega 1^*}$



5. What should be the size of absorber mass?

   So when $\omega = \omega 1^* = \omega 2^*$
   We find A1 = 0, then,
   $A2 = \left(\frac{P0}{k1}\right)\frac{1}{-\mu\left(\frac{\omega 2^*}{\omega 1^*}\right)^2} = \left(\frac{P0}{k1}\right)\left(-\frac{K1}{K2}\right) = -\frac{P0}{k2}$ Eq. (A)
   OR
   $K2A2 = -P0 \Rightarrow m2\omega 2^{*2}A2 = -P0$ Since $\omega = \omega 2^*$
   $\Rightarrow m2\omega^2 A2 = -P0$ Eq. (B)

Here we find that, the absorber mass applied an opposite force of equal magnitude. The parameters for the absorber i.e K2 and m2 will depend upon how much Displacement we can allow for absorber mass i.e. A2.

K2 = $-\frac{P0}{A2}$ From Eq. (A)
M2 = $-\frac{P0}{A2\omega^2}$ From Eq. (B)

6. Here we find that if μ is small the operating frequency range will be small and vice versa and large m2 will create some practical problems.In synchronous machinery, which operate at nearly constant frequency. Such an absorber find suitable application. In transmission Line towers, dumble shape masses are used (Where wind induced vibrations dominant).

CHAPTER 4

EXPERIMENTAL STUDY

Modeling and Analysis

The structure consists of columns, beams and slabs. Analysis of the structure is done using ETABS 2018. Dead load, live load and earthquake load are considered for analysis.

Material Property

Grade of concrete = M30

Grade of rebar = HYSD500

Unit weight of concrete = 25 KN/m^3

Unit weight of steel = 78.0KN/m^3

Geometry of Model

Size of beam for G+4, G+10, G+14, G+18, G+22 storey = 500 x 400mm

Size of column for G+4 = 400 x 600mm

Size of column for G+10 = 750 x 500mm

Size of column for G+14, G+18, G+22 = 750 x 750mm

Thickness of slab = 175mm

Thickness of wall = 250mm

Story height = 3.3m

Load (EL)

The earthquake load is considered as per the IS 1893-2006 (Part 1). The factors considered are

Zone factors = 0.24 (zone 4)

Importance factor For G+4, G+10 And G+14 Storey = 1.0

Importance factor For G+18 And G+22 Storey = 1.2

Response reduction factor = 5

Soil condition = Medium stiff soil

Damping = 5%

Loads

Live Load = 3 kN/m^2

Dead Load = 12 kN/m^2

TIME PERIOD

Time period = $0.075\ h^{0.75}$
$= 0.075\ (16.5)^{0.75}$

Time period = 0.614 Seconds

For design horizontal seismic coefficient A_h for a structure is determined by :

$A_h = Z/2 * I/R * S_a/g$

$A_h = 0.24/2 * 1/5 * 1.36/T$

$A_h = 0.053$

Time History Analysis With and without damper

Now, the structure consists of columns, beams, slabs and water tank as tuned mass damper. Analysis of the structure is done using ETABS 2018.

El centro earthquake are considered for time history analysis.

It was the first major earthquake to be recorded by a strong-motion seismograph located next to a fault rupture. It was the strongest recorded earthquake to hit the Imperial Valley, and caused widespread damage to irrigation systems and led to the deaths of nine people.

Time History Analysis

- In Time history analysis the structural response is calculated at a number of corresponding instants of time.
- In other term, Time histories are obtained from the structural response to a given input and a consequence.
- El centro earthquake are considered for time history analysis.
- The evolution of response time can not be measured in response spectrum analysis.

About the Models

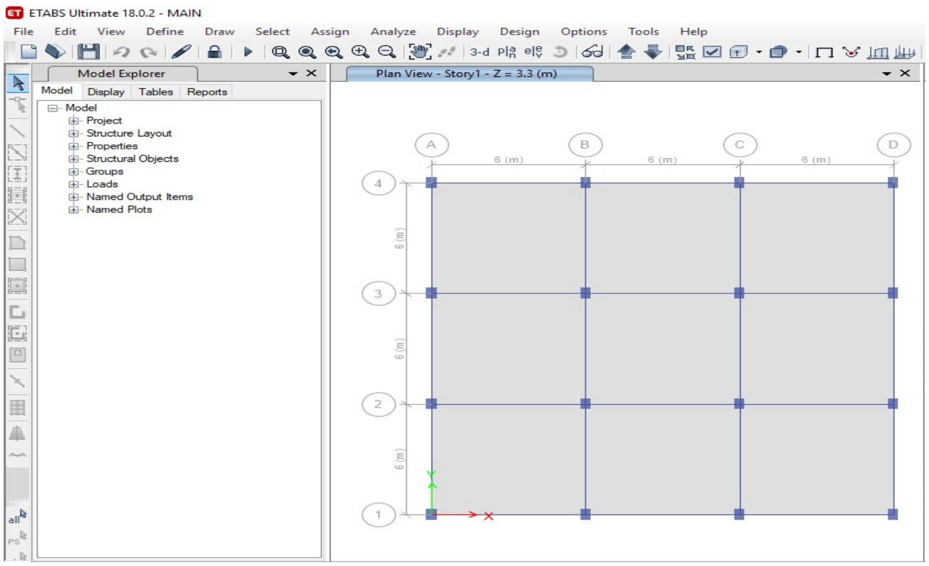


Figure 3 : Plan of the Model

3D View

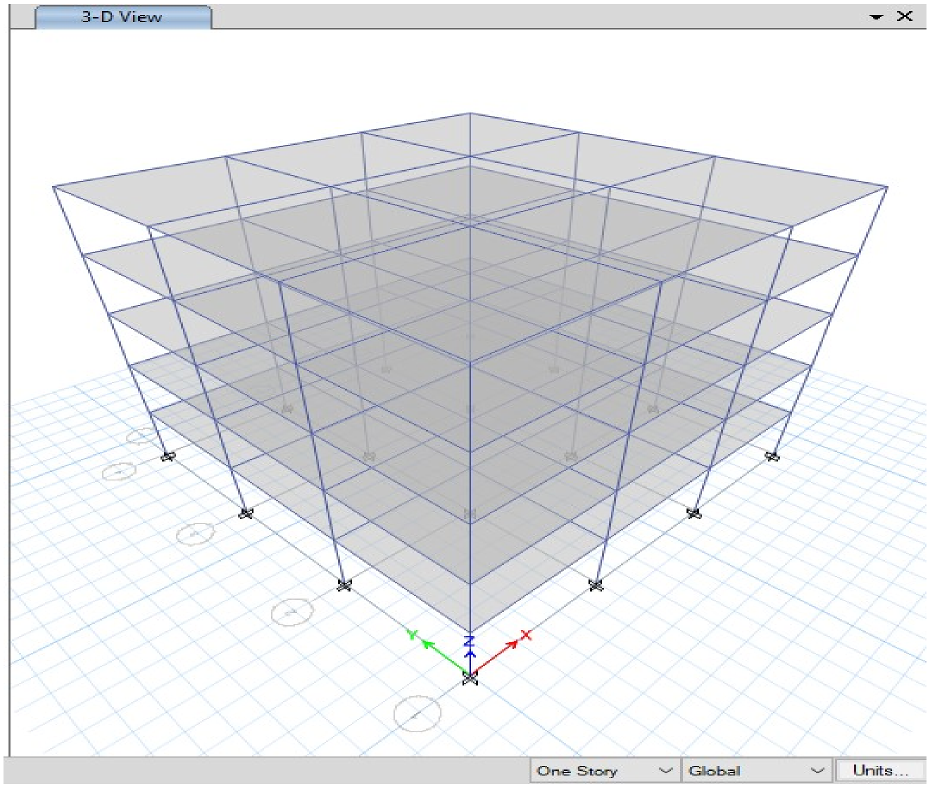


Figure 4: Model of G+4 Structure Without Tank

Analysis Result of G+4 Without water tank Using Time History Analysis

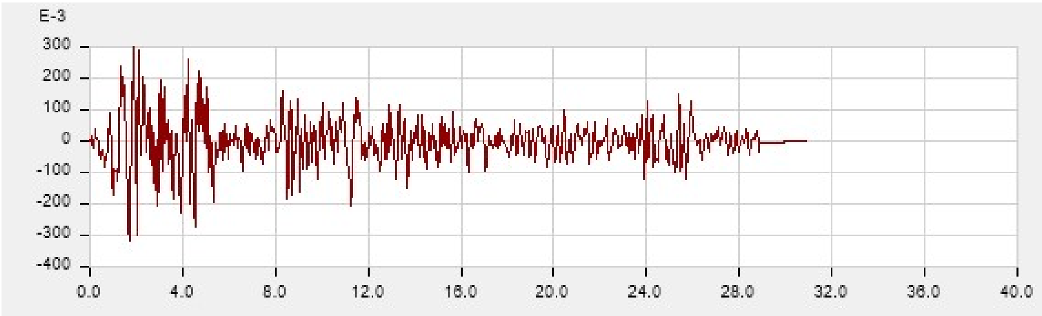


Figure 5: Time History Graph

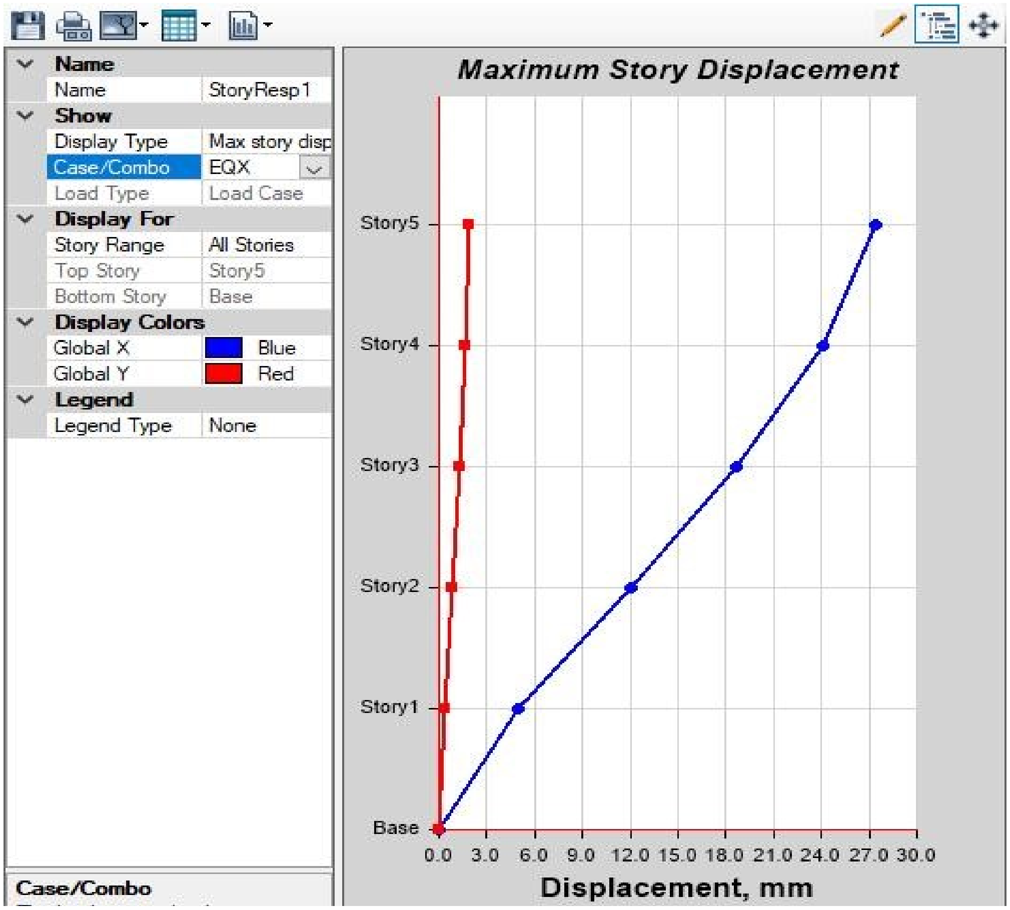


Figure 6: Maximum storey Displacement of G+4 without water tank in the Direction of X for EQX

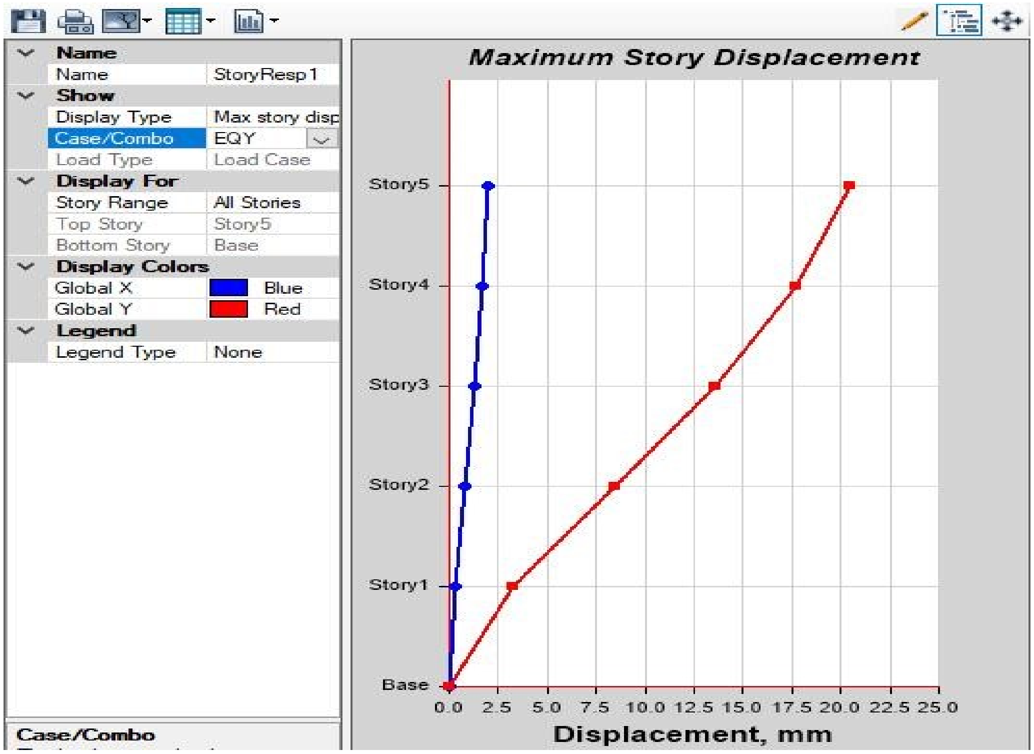


Figure 7: Maximum storey Displacement of G+4 without water tank in the Direction of Y for EQY

1	TABLE: Base Reactions												
2	Output Case	Case Type	Step Type	Step Number	FX	FY	FZ	MX	MY	MZ	X	Y	Z
3					kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
4	Modal	LinModEigen	Mode	1	-1.5945	0	0	0	-18.9117	14.3507	0	0	0
5	Modal	LinModEigen	Mode	2	0	2.2218	0	-26.7102	0	19.9958	0	0	0
6	Modal	LinModEigen	Mode	3	0	0	0	0	0	-20.6884	0	0	0
7	Modal	LinModEigen	Mode	4	5.281	0	0	9.077E-06	-11.9761	-47.5291	0	0	0
8	Modal	LinModEigen	Mode	5	0	8.2621	1.399E-06	12.9622	0.0001	74.3587	0	0	0
9	Modal	LinModEigen	Mode	6	0	0	0	0.00000124	5.222E-06	-73.0061	0	0	0
10	Modal	LinModEigen	Mode	7	9.6772	2.684E-06	-0.0001	-0.001	27.5692	-87.0952	0	0	0
11	Modal	LinModEigen	Mode	8	0	17.7557	0	-52.4156	0.0014	159.8017	0	0	0
12	Modal	LinModEigen	Mode	9	0	0	-5.639E-07	-1.456E-05	-7.545E-06	-149.0364	0	0	0
13	Modal	LinModEigen	Mode	10	-13.0525	-2.714E-06	0.0001	0.0026	-0.4833	117.4723	0	0	0
14	Modal	LinModEigen	Mode	11	-10.7245	-0.0000157	-0.0003	-0.0068	-2.6653	96.5204	0	0	0
15	Modal	LinModEigen	Mode	12	-2.744E-06	-4.051E-06	124.8449	1123.6029	-1123.608	5.968E-06	0	0	0
16	Dead	LinStatic			0	0	11967.9649	107711.684	-107711.684	0	0	0	0
17	Live	LinStatic			0	0	4860	43740	-43740	0	0	0	0
18	SIDL	LinStatic			0	0	10665	95985	-95985	0	0	0	0
19	EQY	LinStatic			0	-1259.3305	0	16943.0738	0	-12467.372	0	0	0
20	EQX	LinStatic			-1259.3305	0	0	0	-16943.0738	12467.3719	0	0	0
21	TH-X	NonModHist	Max		1070.3373	0.00003001	0.0004	0.0061	10527.0052	7756.8625	0	0	0
22	TH-X	NonModHist	Min		-861.8736	-0.00001474	-0.0006	-0.0073	-8966.8563	-9633.0353	0	0	0
23	TH-Y	NonModHist	Max		9.102E-06	1146.2887	0.00002307	8486.9359	0.02	10316.5979	0	0	0
24	TH-Y	NonModHist	Min		-3.491E-06	-780.2821	-2.275E-05	-10492.802	-0.0103	-7022.5385	0	0	0
25	Static	LinStatic			-8000	0	0	0	-132000	72000	0	0	0

Table 1: Base Reactions

	Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
1	TABLE: Modal Participating Mass Ratios														
2	Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
3			sec												
4	Modal	1	1.056	0.8405	0	0	0.8405	0	0	0	0.0645	0	0	0.0645	0
5	Modal	2	0.89	0	0.8216	0	0.8405	0.8216	0	0.0732	0	0	0.0732	0.0645	0
6	Modal	3	0.841	0	0	0	0.8405	0.8216	0	0	0	0.8293	0.0732	0.0645	0.8293
7	Modal	4	0.342	0.1012	0	0	0.9417	0.8216	0	0	0.2634	0	0.0732	0.3278	0.8293
8	Modal	5	0.278	0	0.1078	0	0.9417	0.9294	0	0.2489	0	0	0.3221	0.3278	0.8293
9	Modal	6	0.266	0	0	0	0.9417	0.9294	0	0	0	0.1041	0.3221	0.3278	0.9333
10	Modal	7	0.197	0.0372	0	0	0.9789	0.9294	0	0	0.0321	0	0.3221	0.3599	0.9333
11	Modal	8	0.151	0	0.0433	0	0.9789	0.9727	0	0.0362	0	0	0.3584	0.3599	0.9333
12	Modal	9	0.148	0	0	0	0.9789	0.9727	0	0	0	0.0413	0.3584	0.3599	0.9746
13	Modal	10	0.138	0.0163	0	0	0.9952	0.9727	0	0	0.0277	0	0.3584	0.3877	0.9746
14	Modal	11	0.111	0.0047	0	0	0.9999	0.9727	0	0	0.0076	0	0.3584	0.3953	0.9746
15	Modal	12	0.109	0	0	0.5912	0.9999	0.9727	0.5912	0	0	0	0.3584	0.3953	0.9746

Table 2 : Modal Participating mass ratios

Modeling and time history Analysis of G+4 model with Empty Water Tank

Tank Dimensions :

Length = 3m

Width = 3m

Height = 2m

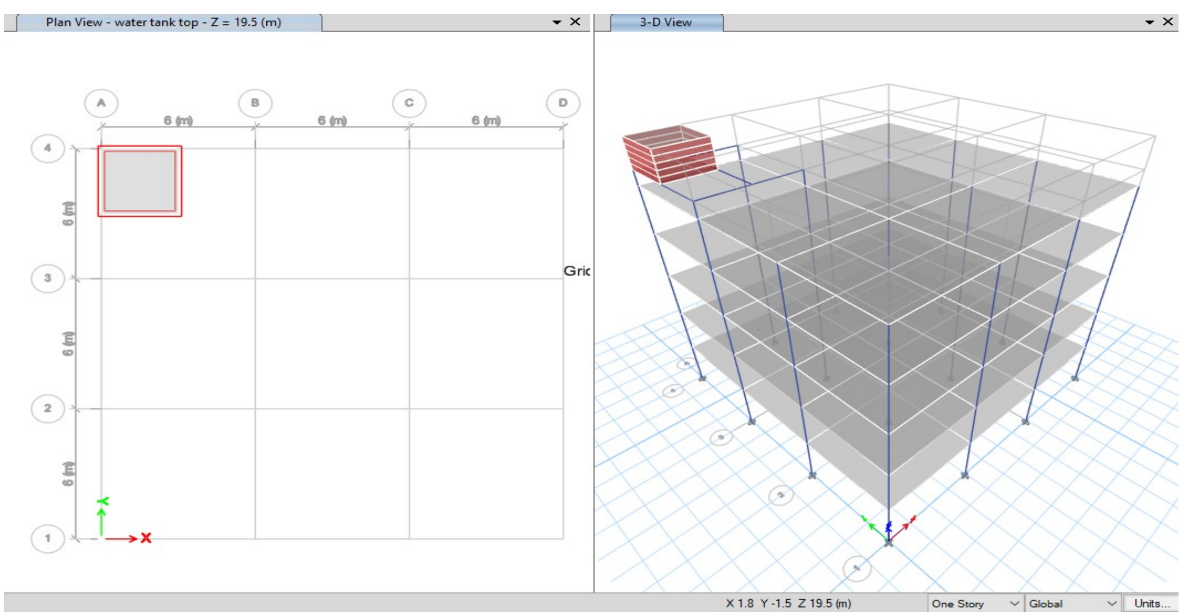


Figure 8 : Plan & 3D view of G+4 Model with Water Tank

Analysis result of Time history analysis with Empty water tank

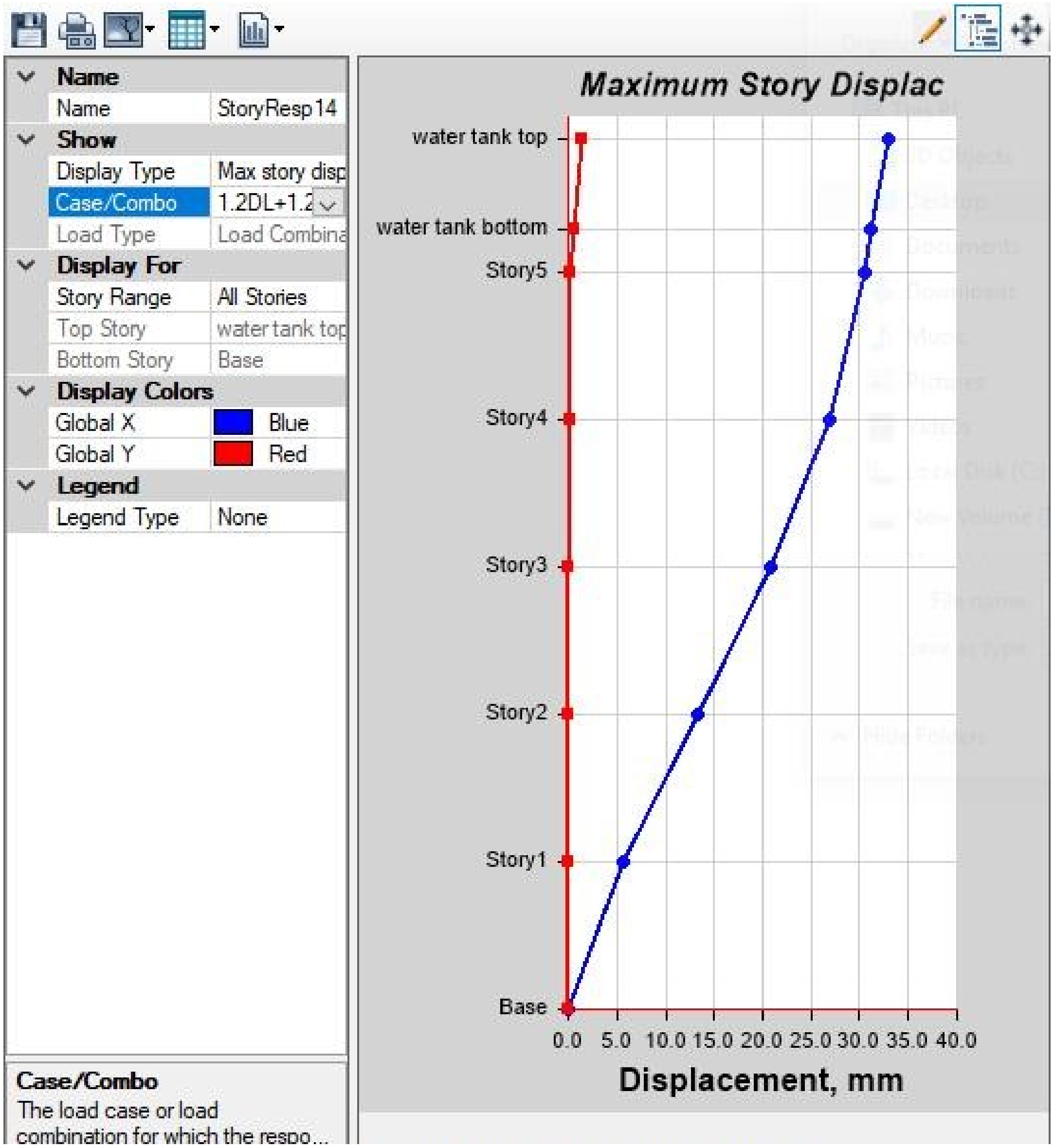


Figure 9: Maximum Storey displacement of G+4 with Empty water tank in the direction of X for EQX

In this load combination, Maximum Storey Displacement is 32.916408MM at top of the water tank.

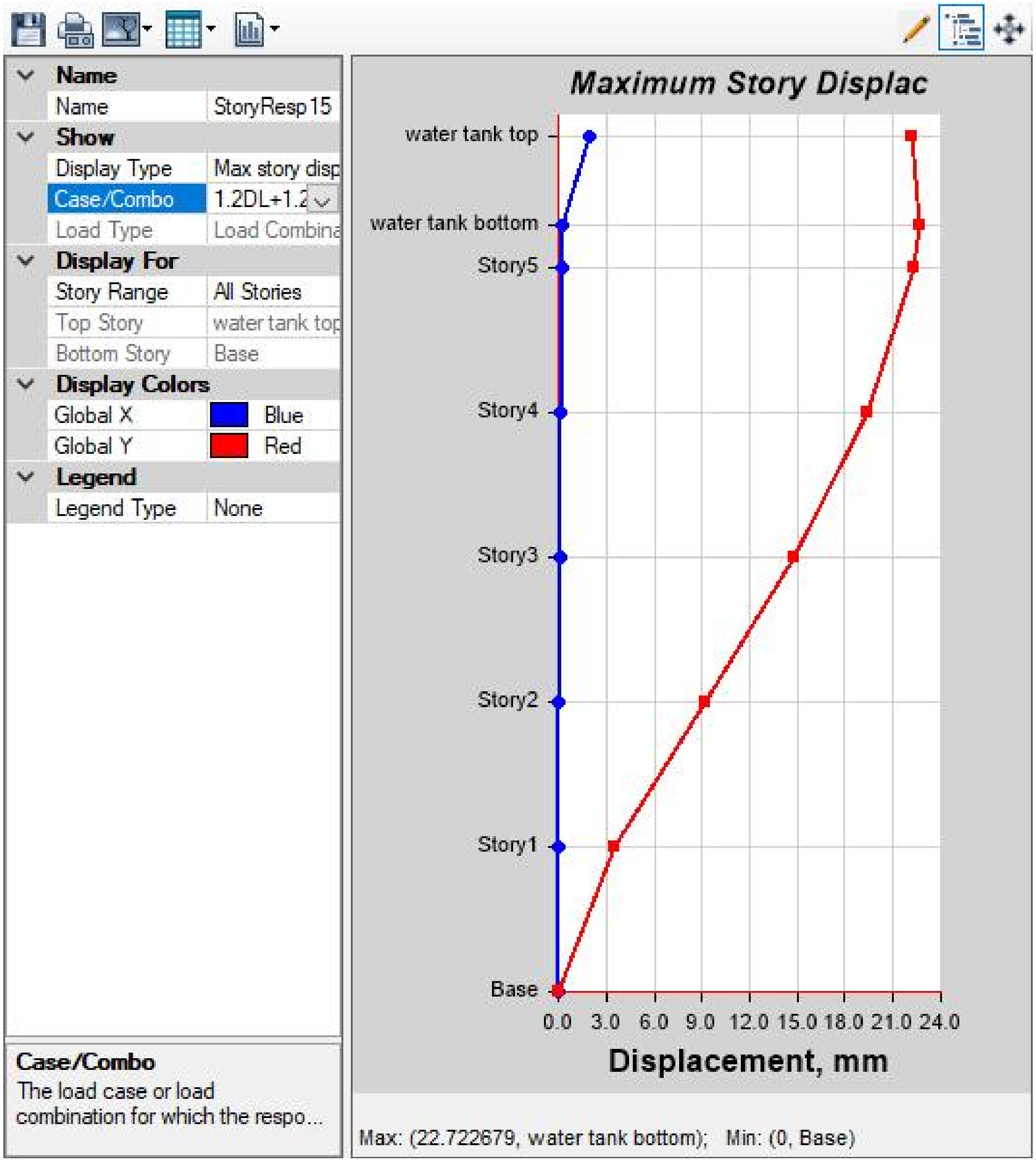


Figure 10: Maximum Storey displacement of G+4 with Empty water tank in the direction of Y for EQY

In this load combination, Maximum Storey Displacement is 22.722679mm at bottom of the water tank.

	TABLE: Modal Participating Mass Ratios													
2	Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
3			sec												
4	Modal	1	1.084	0.8344	0.0001	0	0.8344	0.0001	0	0.0001	0.1658	0.0056	0.0001	0.1658	0.0056
5	Modal	2	0.92	0.0013	0.7164	0	0.8357	0.7165	0	0.1719	0.000003699	0.1051	0.172	0.1658	0.1107
6	Modal	3	0.865	0.0046	0.1052	0	0.8403	0.8217	0	0.0134	0.0001	0.7184	0.1854	0.1658	0.8292
7	Modal	4	0.349	0.101	0	0	0.9412	0.8217	0	6.133E-07	0.6578	0.0005	0.1854	0.8236	0.8296
8	Modal	5	0.286	0.0001	0.0914	0	0.9413	0.9131	0	0.521	0.0004	0.0158	0.7064	0.824	0.8455
9	Modal	6	0.272	0.0004	0.0165	0	0.9417	0.9296	0	0.0916	0.0018	0.0878	0.798	0.8258	0.9333
10	Modal	7	0.199	0.0372	0.000001584	0	0.9789	0.9296	0	0.000005071	0.0841	0.0001	0.798	0.9099	0.9334
11	Modal	8	0.154	0.00004159	0.0312	0	0.979	0.9608	0	0.0694	0.0002	0.0113	0.8673	0.9101	0.9447
12	Modal	9	0.15	0.0002	0.012	0	0.9792	0.9728	0	0.0279	0.001	0.0296	0.8952	0.9111	0.9743
13	Modal	10	0.138	0.0161	0.00001146	0	0.9953	0.9728	0	0.00003171	0.0735	0.0003	0.8953	0.9847	0.9745
14	Modal	11	0.111	0.0047	0	0	1	0.9728	0	0	0.0138	0.0001	0.8953	0.9985	0.9746
15	Modal	12	0.102	0.000001062	0.0084	0	1	0.9812	0	0.0352	0.00002423	0.0112	0.9305	0.9985	0.9858

Table 3: Modal participating mass ratio of G+4 with Empty Water Tank

1	TABLE: Base Reactions												
2	Output Case	Case Type	Step Type	Step Number	FX	FY	FZ	MX	MY	MZ	X	Y	Z
3					kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
4	Modal	LinModEigen	Mode	1	-1.5268	-0.0157	0	0.2151	-18.5048	14.9055	0	0	0
5	Modal	LinModEigen	Mode	2	-0.0833	1.9637	0	-24.2125	-0.8543	11.8182	0	0	0
6	Modal	LinModEigen	Mode	3	-0.1783	-0.8529	0	9.9773	-1.6809	-24.4502	0	0	0
7	Modal	LinModEigen	Mode	4	5.1283	0.0053	0	0.0074	-11.1167	-49.9483	0	0	0
8	Modal	LinModEigen	Mode	5	-0.2137	7.2793	0	10.0682	0.1159	40.9336	0	0	0
9	Modal	LinModEigen	Mode	6	0.5447	3.4005	0	4.197	0.0366	90.3565	0	0	0
10	Modal	LinModEigen	Mode	7	-9.5596	0.0624	0	-0.0918	-27.0603	93.1505	0	0	0
11	Modal	LinModEigen	Mode	8	0.5331	-14.6109	0	42.3043	-0.1588	-60.7089	0	0	0
12	Modal	LinModEigen	Mode	9	1.2718	9.5693	0	-26.1136	-0.4479	198.0071	0	0	0
13	Modal	LinModEigen	Mode	10	-13.0321	0.3472	0	-0.7186	2.2555	136.0959	0	0	0
14	Modal	LinModEigen	Mode	11	10.8295	-0.0267	0	-0.0149	19.3115	-89.1615	0	0	0
15	Modal	LinModEigen	Mode	12	0.1959	17.4281	0	-4.1508	-2.501	-15.6846	0	0	0
16	Dead	LinStatic			0	0	12348.6036	113764.2819	-108407.1138	0	0	0	0
17	Live	LinStatic			0	0	4866.75	43851.375	-43750.125	0	0	0	0
18	SIDL	LinStatic			0	0	10903.5	99596.25	-96450.75	0	0	0	0
19	EQY	LinStatic			0	-1259.9683	0	16956.1043	0	-11330.9494	0	0	0
20	EQX	LinStatic			-1259.9683	0	0	0	-16956.1043	11348.4797	0	0	0
21	LIVE>5	LinStatic			0	0	0	0	0	0	0	0	0
22	WATER TANK PRESSURE	LinStatic			0	0	0	0	0	0	0	0	0
23	TH-X	LinModHist	Max		2101.2578	3.7047	0	23.0741	20699.8669	-8.848	0	0	0
24	TH-X	LinModHist	Min		0.9831	-3.4997	0	-24.1613	0	-19314.3278	0	0	0
25	TH-Y	LinModHist	Max		3.322	2112.0887	0	0	14.6817	18055.6474	0	0	0

	TABLE: Base Reactions												
2	Output Case	Case Type	Step Type	Step Number	FX	FY	FZ	MX	MY	MZ	X	Y	Z
3					kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
26	TH-Y	LinModHist	Min		-3.1383	0.8816	0	-19208.2378	-18.6789	7.9341	0	0	0
27	1.5DL	Combination			0	0	34878.1554	320040.7978	-307286.7957	0	0	0	0
28	1.5DL+1.5LL	Combination			0	0	42178.2804	385817.8603	-372911.9832	0	0	0	0
29	1.2DL+1.2LL+1.2EQY	Combination			0	-1511.9619	33742.6243	329001.6134	-298329.5865	-13597.1393	0	0	0
30	1.2DL+1.2LL-1.2EQY	Combination			0	1511.9619	33742.6243	288306.9631	-298329.5865	13597.1393	0	0	0
31	1.2DL+1.2LL+1.2EQX	Combination			-1511.9619	0	33742.6243	308654.2882	-318676.9117	13618.1756	0	0	0
32	1.2DL+1.2LL-1.2EQX	Combination			1511.9619	0	33742.6243	308654.2882	-277982.2613	-13618.1756	0	0	0
33	1.5DL+1.5EQY	Combination			0	-1889.9524	34878.1554	345474.9543	-307286.7957	-16996.4241	0	0	0
34	1.5DL-EQY	Combination			0	1889.9524	34878.1554	294606.6413	-307286.7957	16996.4241	0	0	0
35	1.5DL+1.5EQX	Combination			-1889.9524	0	34878.1554	320040.7978	-332720.9521	17022.7196	0	0	0
36	1.5DL-1.5EQX	Combination			1889.9524	0	34878.1554	320040.7978	-281852.6392	-17022.7196	0	0	0
37	0.9DL+1.5EQY	Combination			0	-1889.9524	20926.8933	217458.6352	-184372.0774	-16996.4241	0	0	0
38	0.9DL-1.5EQY	Combination			0	1889.9524	20926.8933	166590.3222	-184372.0774	16996.4241	0	0	0
39	0.9DL+1.5EQX	Combination			-1889.9524	0	20926.8933	192024.4787	-209806.2339	17022.7196	0	0	0
40	0.9DL-1.5EQX	Combination			1889.9524	0	20926.8933	192024.4787	-158937.9209	-17022.7196	0	0	0
41	UDCon15	Combination			0	0	33742.6243	308654.2882	-298329.5865	0	0	0	0
42	UDCon16	Combination			0	0	33742.6243	308654.2882	-298329.5865	0	0	0	0
43	UDCon17	Combination			0	0	34878.1554	320040.7978	-307286.7957	0	0	0	0
44	UDCon18	Combination			0	0	34878.1554	320040.7978	-307286.7957	0	0	0	0
45	UDCon19	Combination			0	0	20926.8933	192024.4787	-184372.0774	0	0	0	0
46	UDCon20	Combination			0	0	20926.8933	192024.4787	-184372.0774	0	0	0	0
47	DL+LL	Combination			0	0	28118.8536	257211.9069	-248607.9888	0	0	0	0

Table 4: Base Reactions of G+4 with Empty water tank

Modeling and analysis of G+4 model with Filled Water tank

Tank Dimensions :

Length = 3m

Width = 3m

Height = 2m

Liquid Mass = 10kn

Water pressure on wall = H x Density of water
= 2m x 10Kn/m^3
= 20 kN/m^2

Calculation for 10 thousand liter water tank :

Capacity of tank = 10000 liter

Tank Area = 3m x 3m = $9m^2$

So, 10000 liter = 100kn

Water load at bottom = 100/9 = $11.1kn/m^2$

When water Load is Half = 11.1/2
= $5.55kn/m^2$

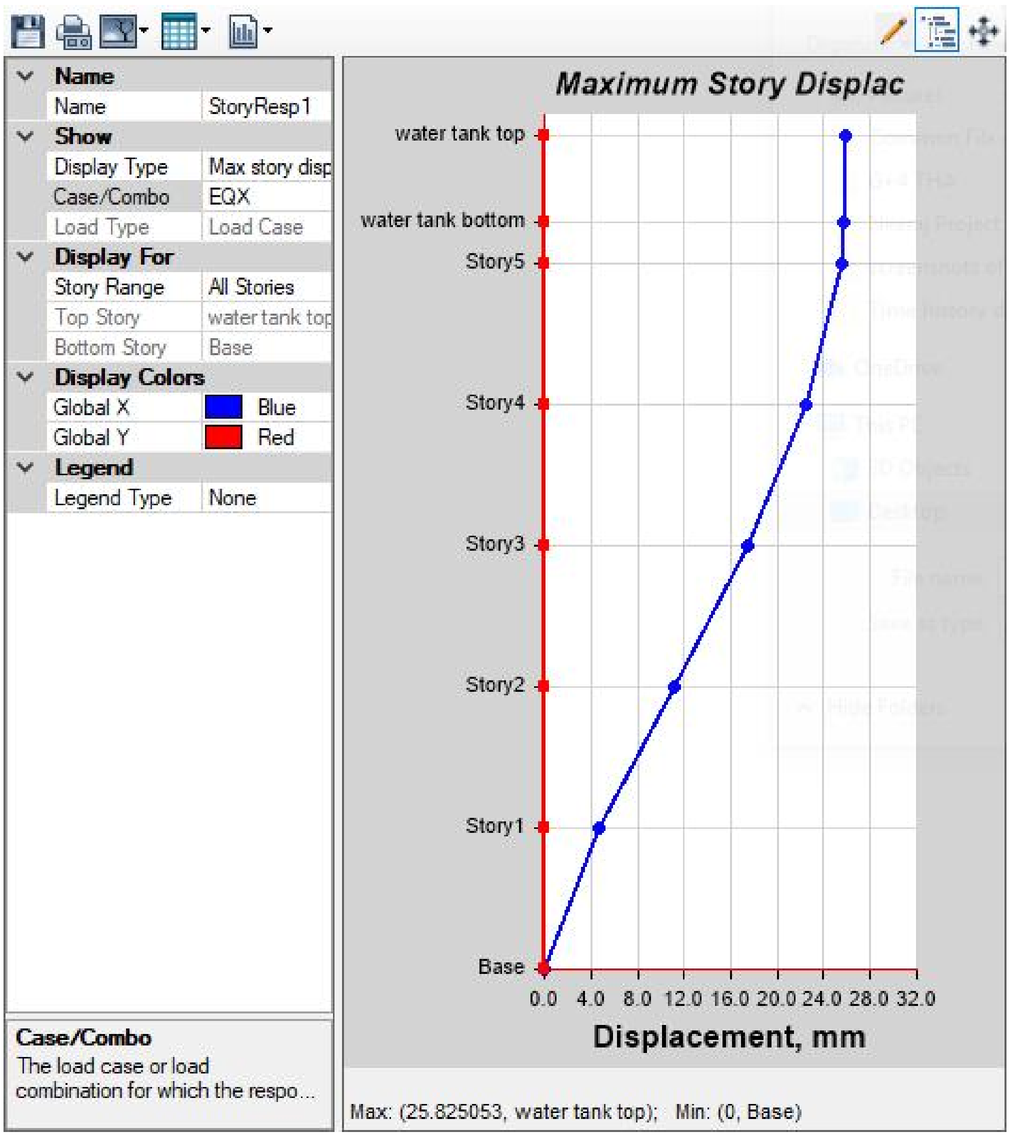


Figure11: Maximum Storey displacement of G+4 with Filled water tank for Earthquake in X-Direction

In this, Maximum Storey Displacement is 25.825053mm at top of the water tank.

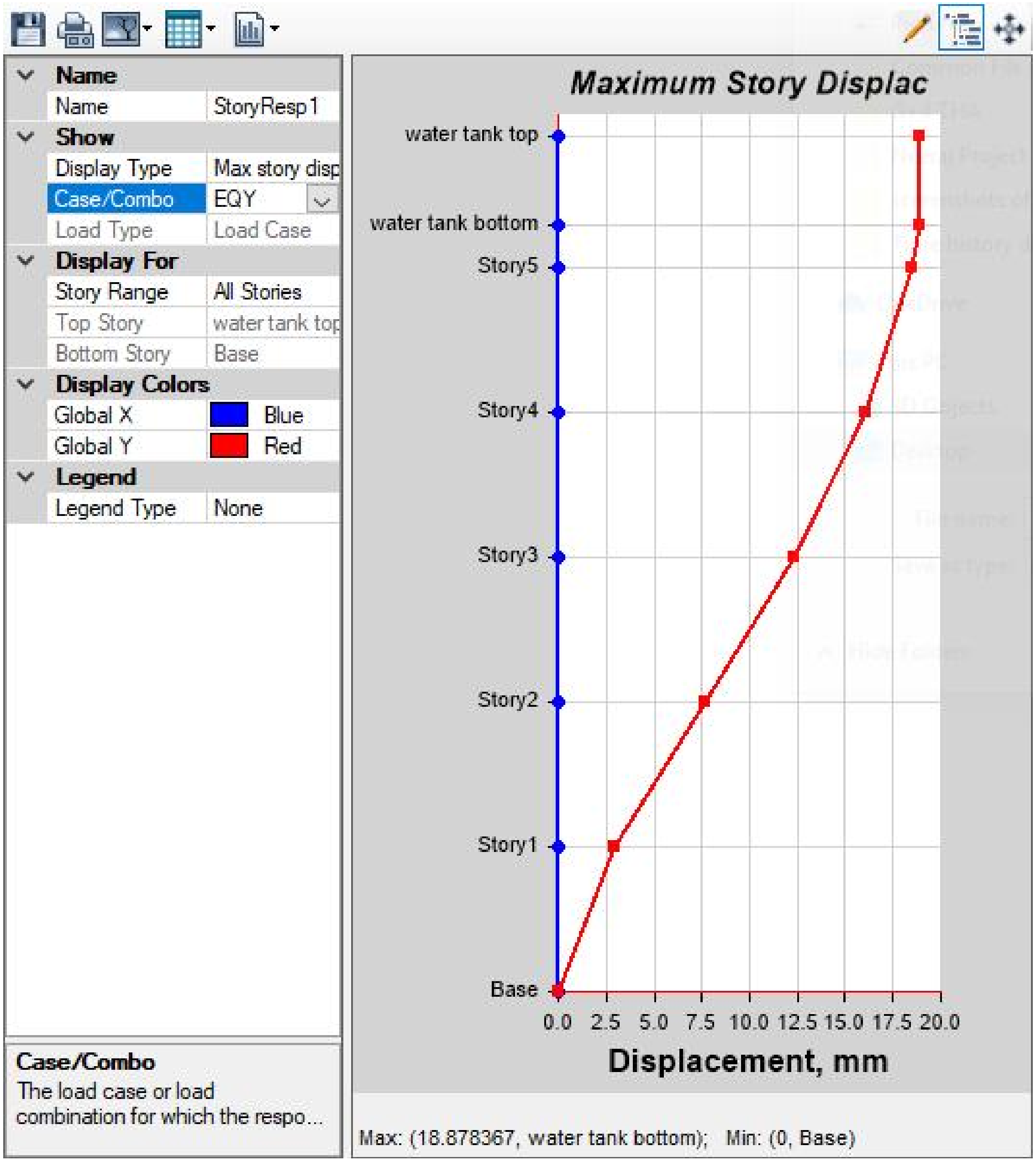


Figure 12: Maximum Storey displacement of G+4 with Filled water tank for Earthquake in Y- Direction

In this direction, Maximum Storey Displacement is 18.878367mm at bottom of the water tank.

1	TABLE: Modal Participating Mass Ratios														
2	Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
3			sec												
4	Modal	1	1.088	0.8326	0.0001	0	0.8326	0.0001	0	0.0001	0.1661	0.0073	0.0001	0.1661	0.0073
5	Modal	2	0.925	0.002	0.6973	0	0.8346	0.6974	0	0.1698	0.000008187	0.1237	0.1699	0.1661	0.131
6	Modal	3	0.866	0.0056	0.1243	0	0.8402	0.8217	0	0.0159	0.0001	0.6981	0.1857	0.1662	0.8291
7	Modal	4	0.35	0.1008	0	0	0.9411	0.8217	0	0.000001238	0.6565	0.0006	0.1857	0.8226	0.8298
8	Modal	5	0.287	0.0001	0.0885	0	0.9412	0.9101	0	0.504	0.0006	0.0186	0.6897	0.8232	0.8483
9	Modal	6	0.273	0.0005	0.0194	0	0.9417	0.9295	0	0.1079	0.0023	0.0849	0.7976	0.8256	0.9332
10	Modal	7	0.199	0.0372	0.000002265	0	0.9789	0.9295	0	0.000007369	0.0843	0.0002	0.7976	0.9098	0.9334
11	Modal	8	0.155	0.0001	0.0297	0	0.9789	0.9592	0	0.0662	0.0003	0.0126	0.8637	0.9101	0.946
12	Modal	9	0.15	0.0003	0.0135	0	0.9792	0.9727	0	0.0313	0.0012	0.0281	0.895	0.9113	0.9742
13	Modal	10	0.139	0.0161	0.00001683	0	0.9953	0.9727	0	0.00004596	0.0733	0.0003	0.8951	0.9846	0.9745
14	Modal	11	0.111	0.0047	0	0	1	0.9727	0	0.000001148	0.0139	0.0001	0.8951	0.9985	0.9746
15	Modal	12	0.102	0.000002064	0.0084	0	1	0.9811	0	0.035	0.00003496	0.011	0.9301	0.9986	0.9856

Table 5: Modal participating mass ratio of G+4 with filled water tank

1	TABLE: Base Reactions												
2	Output Case	Case Type	Step Type	Step Number	FX	FY	FZ	MX	MY	MZ	X	Y	Z
3					kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
4	Modal	LinModEigen	Mode	1	1.5174	0.0198	0	-0.2723	18.4383	-14.9539	0	0	0
5	Modal	LinModEigen	Mode	2	-0.1025	1.9213	0	-23.7746	-1.0579	11.0979	0	0	0
6	Modal	LinModEigen	Mode	3	-0.197	-0.9243	0	10.8359	-1.8673	-24.5816	0	0	0
7	Modal	LinModEigen	Mode	4	-5.1064	-0.0077	0	-0.0088	11.0619	50.2146	0	0	0
8	Modal	LinModEigen	Mode	5	0.2618	-7.1098	0	-9.8143	-0.1729	-37.8137	0	0	0
9	Modal	LinModEigen	Mode	6	0.6036	3.6787	0	4.5919	-0.0174	91.0016	0	0	0
10	Modal	LinModEigen	Mode	7	9.5361	-0.0744	0	0.1045	26.9516	-93.8836	0	0	0
11	Modal	LinModEigen	Mode	8	-0.6385	14.152	0	-40.9276	0.0669	53.4968	0	0	0
12	Modal	LinModEigen	Mode	9	1.419	10.1373	0	-27.7853	-0.3285	198.202	0	0	0
13	Modal	LinModEigen	Mode	10	-13.0115	0.4206	0	-0.8942	2.2024	138.6071	0	0	0
14	Modal	LinModEigen	Mode	11	-10.8558	0.0819	0	-0.0089	-19.3861	87.994	0	0	0
15	Modal	LinModEigen	Mode	12	-0.2708	-17.2225	0	4.1526	2.6084	15.9226	0	0	0
16	Dead	LinStatic			0	0	12348.6036	113764.2819	-108407.1138	0	0	0	0
17	Live	LinStatic			0	0	4956.75	45336.375	-43885.125	0	0	0	0
18	SIDL	LinStatic			0	0	10903.5	99596.25	-96450.75	0	0	0	0
19	EQY	LinStatic			0	-1259.9683	0	16956.1043	0	-11330.9494	0	0	0
20	EQX	LinStatic			-1259.9683	0	0	0	-16956.1043	11348.4797	0	0	0
21	LIVE>5	LinStatic			0	0	99.9	1648.35	-149.85	0	0	0	0
22	WATER TANK PRESSURE	LinStatic			0	0	0	0	0	0	0	0	0
23	TH-X	NonModHist	Max		2107.9816	5.2044	0	29.4213	20812.7098	-8.8481	0	0	0
24	TH-X	NonModHist	Min		0.9831	-4.9178	0	-30.1388	0	-19428.4282	0	0	0
25	TH-Y	NonModHist	Max		4.6668	2120.6415	0	0	18.4014	18107.4382	0	0	0
26	TH-Y	NonModHist	Min		-4.4098	0.8816	0	-19354.8881	-22.4067	7.9341	0	0	0
27	DL+LL	Combination			0	0	28308.7536	260345.2569	-248892.8388	0	0	0	0

Table 6: Base reactions for G+4 with Filled water tank

Modeling and analysis of G+4 model with Half Filled Water tank

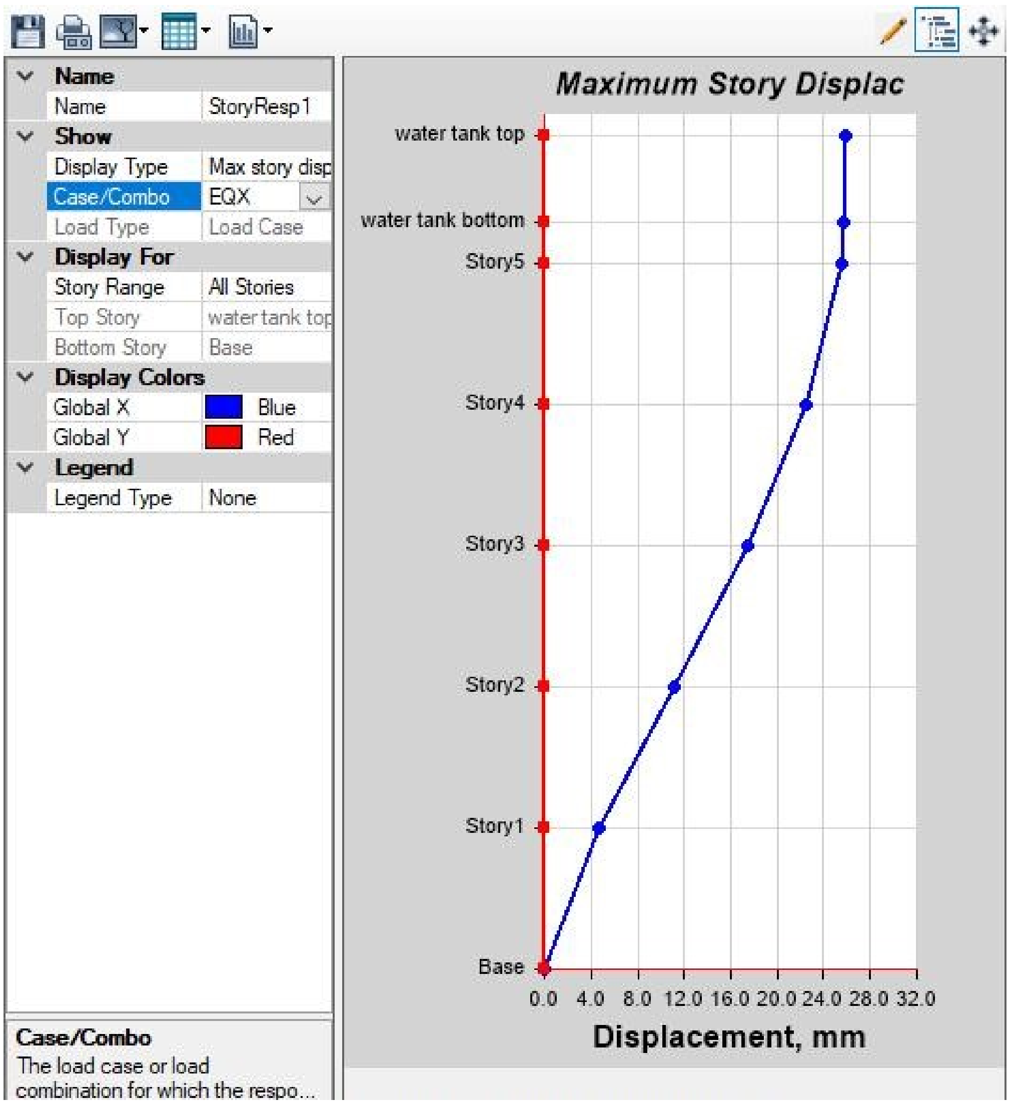


Figure 13: Maximum Storey displacement of G+4 with Half filled water tank for Earthquake in X- Direction

In this, Maximum Storey Displacement is 26.958224mm at top of the water tank.

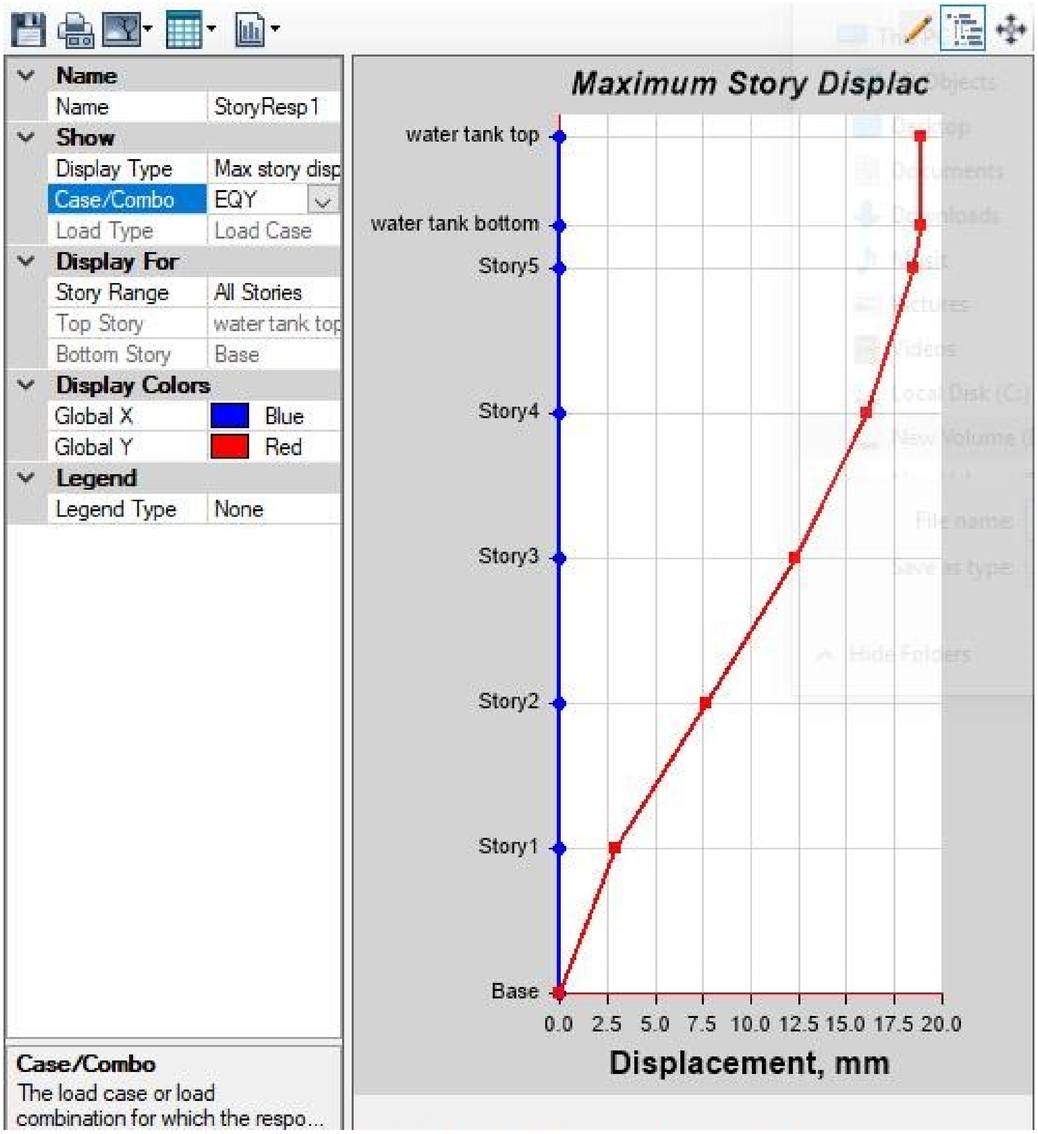


Figure 14: Maximum Storey displacement of G+4 with Half filled water tank for Earthquake in Y- Direction.

In this, Maximum Storey Displacement is 19.115142mm at bottom of the water tank.

	TABLE: Modal Participating Mass Ratios														
2	Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
3			sec												
4	Modal	1	1.086	0.8335	0.0001	0	0.8335	0.0001	0	0.0001	0.1659	0.0064	0.0001	0.1659	0.0064
5	Modal	2	0.923	0.0016	0.7067	0	0.8351	0.7069	0	0.1708	0.000005611	0.1145	0.1709	0.1659	0.121
6	Modal	3	0.866	0.0051	0.1148	0	0.8403	0.8217	0	0.0147	0.0001	0.7082	0.1855	0.166	0.8291
7	Modal	4	0.349	0.1009	0	0	0.9412	0.8217	0	8.923E-07	0.6571	0.0006	0.1856	0.8231	0.8297
8	Modal	5	0.286	0.0001	0.0899	0	0.9413	0.9116	0	0.5123	0.0005	0.0172	0.6979	0.8236	0.8469
9	Modal	6	0.273	0.0005	0.018	0	0.9417	0.9295	0	0.0999	0.0021	0.0863	0.7978	0.8257	0.9332
10	Modal	7	0.199	0.0372	0.000001905	0	0.9789	0.9295	0	0.000006149	0.0842	0.0002	0.7978	0.9099	0.9334
11	Modal	8	0.155	0.0001	0.0304	0	0.979	0.96	0	0.0677	0.0002	0.012	0.8654	0.9101	0.9454
12	Modal	9	0.15	0.0002	0.0128	0	0.9792	0.9728	0	0.0297	0.0011	0.0289	0.8951	0.9112	0.9742
13	Modal	10	0.139	0.0161	0.000014	0	0.9953	0.9728	0	0.00003846	0.0734	0.0003	0.8952	0.9847	0.9745
14	Modal	11	0.111	0.0047	0	0	1	0.9728	0	0	0.0139	0.0001	0.8952	0.9985	0.9746
15	Modal	12	0.102	0.00000148	0.0084	0	1	0.9812	0	0.0352	0.000029	0.0111	0.9303	0.9986	0.9857

Table 7: Modal participating mass ratio for G+4 with Half filled water tank

	TABLE: Base Reactions												
2	Output Case	Case Type	Step Type	Step Number	FX	FY	FZ	MX	MY	MZ	X	Y	Z
3					kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
4	Modal	LinModEigen	Mode	1	-1.5222	-0.0177	0	0.243	-18.4721	14.9307	0	0	0
5	Modal	LinModEigen	Mode	2	-0.0928	1.9423	0	-23.9923	-0.9546	11.4455	0	0	0
6	Modal	LinModEigen	Mode	3	-0.1878	-0.8897	0	10.4203	-1.7754	-24.5234	0	0	0
7	Modal	LinModEigen	Mode	4	-5.1173	-0.0064	0	-0.0081	11.0896	50.0835	0	0	0
8	Modal	LinModEigen	Mode	5	-0.2377	7.1931	0	9.9402	0.1436	39.3095	0	0	0
9	Modal	LinModEigen	Mode	6	-0.5746	-3.5459	0	-4.4031	-0.0094	-90.7178	0	0	0
10	Modal	LinModEigen	Mode	7	9.5479	-0.0683	0	0.0981	27.0061	-93.5208	0	0	0
11	Modal	LinModEigen	Mode	8	0.5866	-14.3723	0	41.5922	-0.115	-56.8627	0	0	0
12	Modal	LinModEigen	Mode	9	-1.3462	-9.8733	0	27.0078	0.3875	-198.2026	0	0	0
13	Modal	LinModEigen	Mode	10	-13.0221	0.3837	0	-0.8057	2.229	137.3618	0	0	0
14	Modal	LinModEigen	Mode	11	10.8428	-0.051	0	-0.0051	19.3484	-88.5825	0	0	0
15	Modal	LinModEigen	Mode	12	-0.2303	-17.3383	0	4.1517	2.5583	15.7532	0	0	0
16	Dead	LinStatic			0	0	12348.6036	113764.2819	-108407.1138	0	0	0	0
17	Live	LinStatic			0	0	4911.75	44593.875	-43817.625	0	0	0	0
18	SIDL	LinStatic			0	0	10903.5	99596.25	-96450.75	0	0	0	0
19	EQY	LinStatic			0	-1259.9683	0	16956.1043	0	-11330.9494	0	0	0
20	EQX	LinStatic			-1259.9683	0	0	0	-16956.1043	11348.4797	0	0	0
21	LIVE>5	LinStatic			0	0	49.95	824.175	-74.925	0	0	0	0
22	WATER TANK PRESSURE	LinStatic			0	0	0	0	0	0	0	0	0
23	THX	NonModHist	Max		2104.6002	4.4193	0	26.2009	20755.9443	-8.848	0	0	0
24	THX	NonModHist	Min		0.9831	-4.1768	0	-27.1309	0	-19371.2641	0	0	0
25	TH-Y	NonModHist	Max		3.9641	2117.2738	0	0	16.5252	18087.3726	0	0	0
26	TH-Y	NonModHist	Min		-3.7466	0.8818	0	-19287.3263	-20.5577	7.9366	0	0	0
27	DL+LL	Combination			0	0	28213.8036	258778.5819	-248750.4138	0	0	0	0

Table 8: Base reactions for G+4 with Half filled water tank

Modeling and analysis of G+10 model without Water tank using Time history analysis

3D View

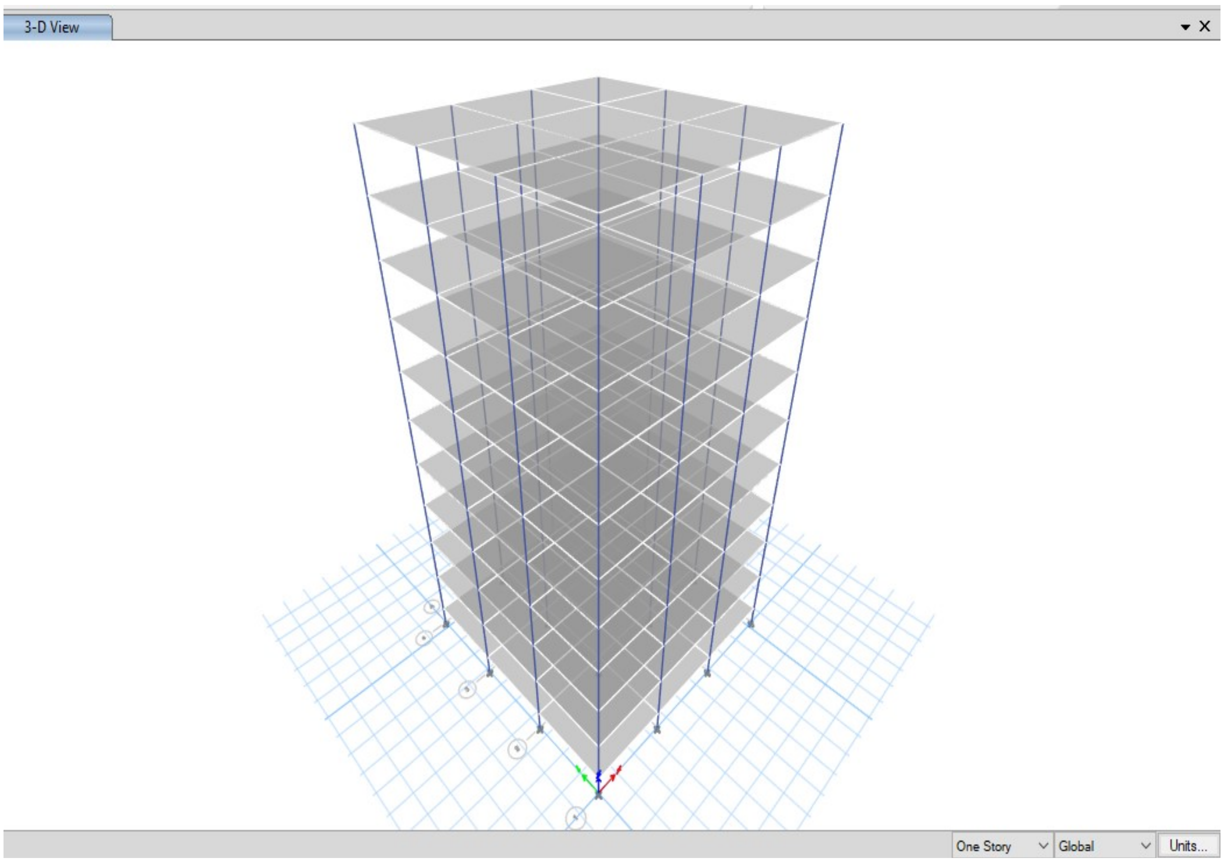


Figure 15: 3D model of G+10 without water tank

TIME PERIOD

Time period = $0.075\ h^{0.75}$
$= 0.075\ (34.5)^{0.75}$

Time period = 1.06 Seconds

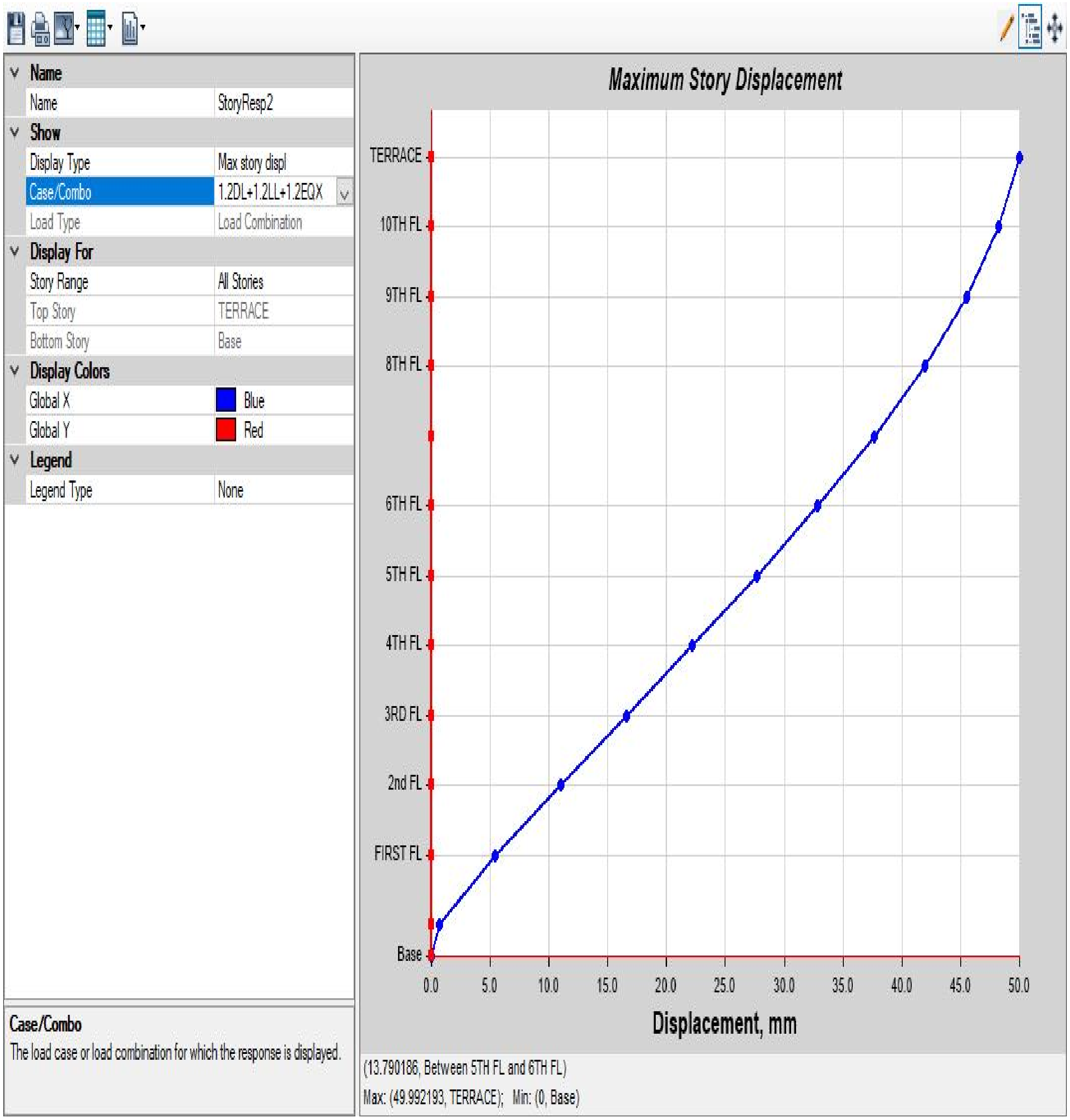


Figure 16: Maximum storey displacement of G+10 without water tank in the direction of X for EQX

In G+10 without water tank model, Maximum Storey Displacement is 49.992193mm at terrace in X- Direction.

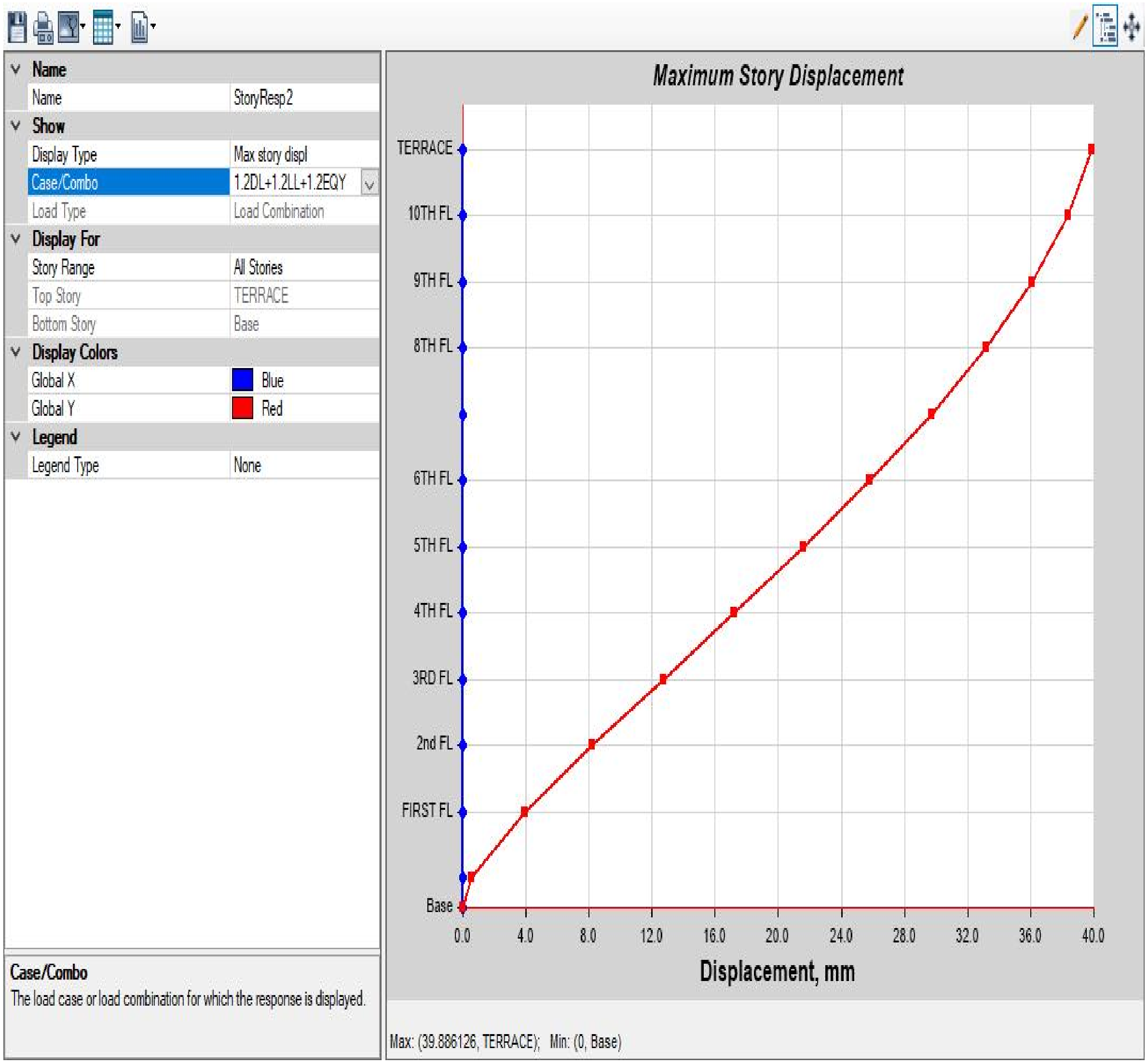


Figure 17: Maximum storey displacement of G+10 without water tank in the direction of Y for EQY

In G+10 without water tank model, Maximum Storey Displacement is 39.886126mm at terrace in Y- Direction.

1	TABLE: Modal Participating Mass Ratios														
2	Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
3			sec												
4	Modal	1	1.578	0.7677	0	0	0.7677	0	0	0	0.2288	0	0	0.2288	0
5	Modal	2	1.397	0	0.7588	0	0.7677	0.7588	0	0.2385	0	0	0.2385	0.2288	0
6	Modal	3	1.265	0	0	0	0.7677	0.7588	0	0	0	0.7698	0.2385	0.2288	0.7698
7	Modal	4	0.516	0.0946	0	0	0.8623	0.7588	0	0	0.4402	0	0.2385	0.669	0.7698
8	Modal	5	0.45	0	0.0977	0	0.8623	0.8565	0	0.422	0	0	0.6605	0.669	0.7698
9	Modal	6	0.413	0	0	0	0.8623	0.8565	0	0	0	0.0902	0.6605	0.669	0.86
10	Modal	7	0.298	0.0336	0	0	0.8959	0.8565	0	0	0.0492	0	0.6605	0.7183	0.86
11	Modal	8	0.253	0	0.0359	0	0.8959	0.8924	0	0.0523	0	0	0.7128	0.7183	0.86
12	Modal	9	0.238	0	0	0	0.8959	0.8924	0	0	0	0.0345	0.7128	0.7183	0.8945
13	Modal	10	0.206	0.0179	0	0	0.9137	0.8924	0	0	0.0589	0	0.7128	0.7771	0.8945
14	Modal	11	0.169	0	0.02	0	0.9137	0.9123	0	0.0614	0	0	0.7743	0.7771	0.8945
15	Modal	12	0.162	0	0	0	0.9137	0.9123	0	0	0	0.0189	0.7743	0.7771	0.9135

Table 9: Modal participating mass ratio of G+10 without water tank

1	TABLE: Base Reactions											
2	Output Case	Case Type	Step Type	FX	FY	FZ	MX	MY	MZ	X	Y	Z
3				kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
4	Dead	LinStatic		0	0	29982.1467	269839.3199	-269839.3199	0	0	0	0
5	Live	LinStatic		0	0	10692	96228	-96228	0	0	0	0
6	SIDL	LinStatic		0	0	23463	211167	-211167	0	0	0	0
7	EQY	LinStatic		0	-2504.1444	0	67525.6309	0	-22537.2993	0	0	0
8	EQX	LinStatic		-2504.1444	0	0	0	-67525.6309	22537.2993	0	0	0
9	LIVE>5	LinStatic		0	0	0	0	0	0	0	0	0
10	WATER TANK PRESSURE	LinStatic		0	0	0	0	0	0	0	0	0
11	TH-X	NonModHist	Max	2103.749	0.0002	0	0	40536.1153	-2.9829	0	0	0
12	TH-X	NonModHist	Min	0.3314	0	0	-0.0003	0	-18933.7376	0	0	0
13	TH-Y	NonModHist	Max	0.00004269	2298.3934	0	0	0.00002124	20685.5403	0	0	0
14	TH-Y	NonModHist	Min	0	0.335	0	-41122.3579	-0.000003801	3.015	0	0	0
15	1.5DL	Combination		0	0	80167.72	721509.4799	-721509.4799	0	0	0	0
16	1.5DL+1.5LL	Combination		0	0	96205.72	865851.4799	-865851.4799	0	0	0	0
17	1.2DL+1.2LL+1.2EQY	Combination		0	-3004.9732	76964.576	773711.9409	-692681.1839	-27044.7592	0	0	0
18	1.2DL+1.2LL-1.2EQY	Combination		0	3004.9732	76964.576	611650.4268	-692681.1839	27044.7592	0	0	0
19	1.2DL+1.2LL+1.2EQX	Combination		-3004.9732	0	76964.576	692681.1839	-773711.9409	27044.7592	0	0	0
20	1.2DL+1.2LL-1.2EQX	Combination		3004.9732	0	76964.576	692681.1839	-611650.4268	-27044.7592	0	0	0
21	1.5DL+1.5EQY	Combination		0	-3756.2166	80167.72	822797.9262	-721509.4799	-33805.949	0	0	0
22	1.5DL-1.5EQY	Combination		0	3756.2166	80167.72	620221.0335	-721509.4799	33805.949	0	0	0
23	1.5DL+1.5EQX	Combination		-3756.2166	0	80167.72	721509.4799	-822797.9262	33805.949	0	0	0
24	1.5DL-1.5EQX	Combination		3756.2166	0	80167.72	721509.4799	-620221.0335	-33805.949	0	0	0
25	0.9DL+1.5EQY	Combination		0	-3756.2166	48100.632	534194.1342	-432905.6879	-33805.949	0	0	0
26	0.9DL-1.5EQY	Combination		0	3756.2166	48100.632	331617.2416	-432905.6879	33805.949	0	0	0
27	0.9DL+1.5EQX	Combination		-3756.2166	0	48100.632	432905.6879	-534194.1342	33805.949	0	0	0
28	0.9DL-1.5EQX	Combination		3756.2166	0	48100.632	432905.6879	-331617.2416	-33805.949	0	0	0
29	DL+LL	Combination		0	0	64137.1467	577234.3199	-577234.3199	0	0	0	0

Table 10: Base reaction of G+10 without water tank

Modeling and analysis of G+10 model with Empty, Filled & Half filled Water tank

Tank Dimensions :

Length = 3m

Width = 3m

Height = 2m

3D View

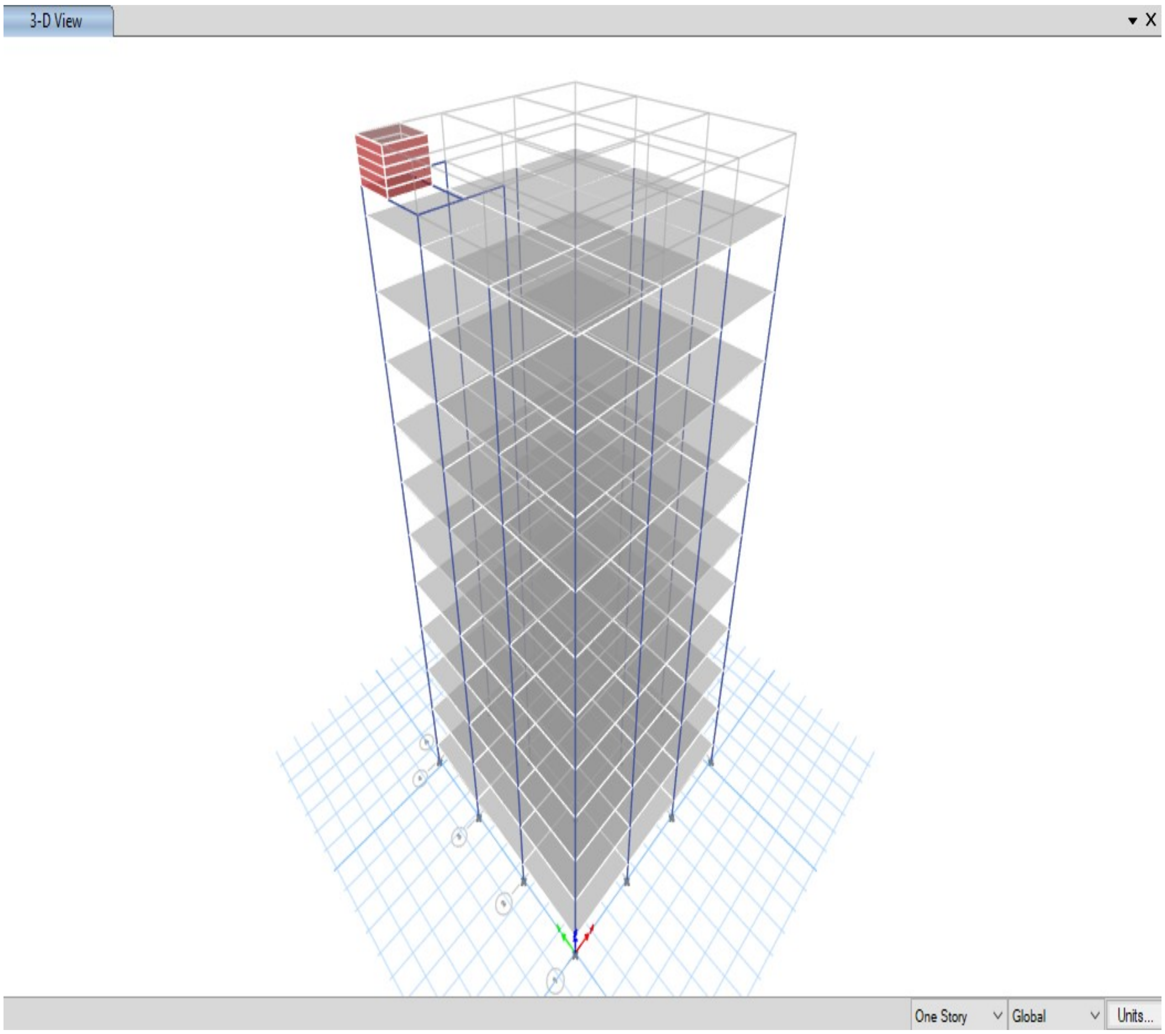


Figure 18: 3D view of G+10 Model with Empty, Filled & Half filled water tank

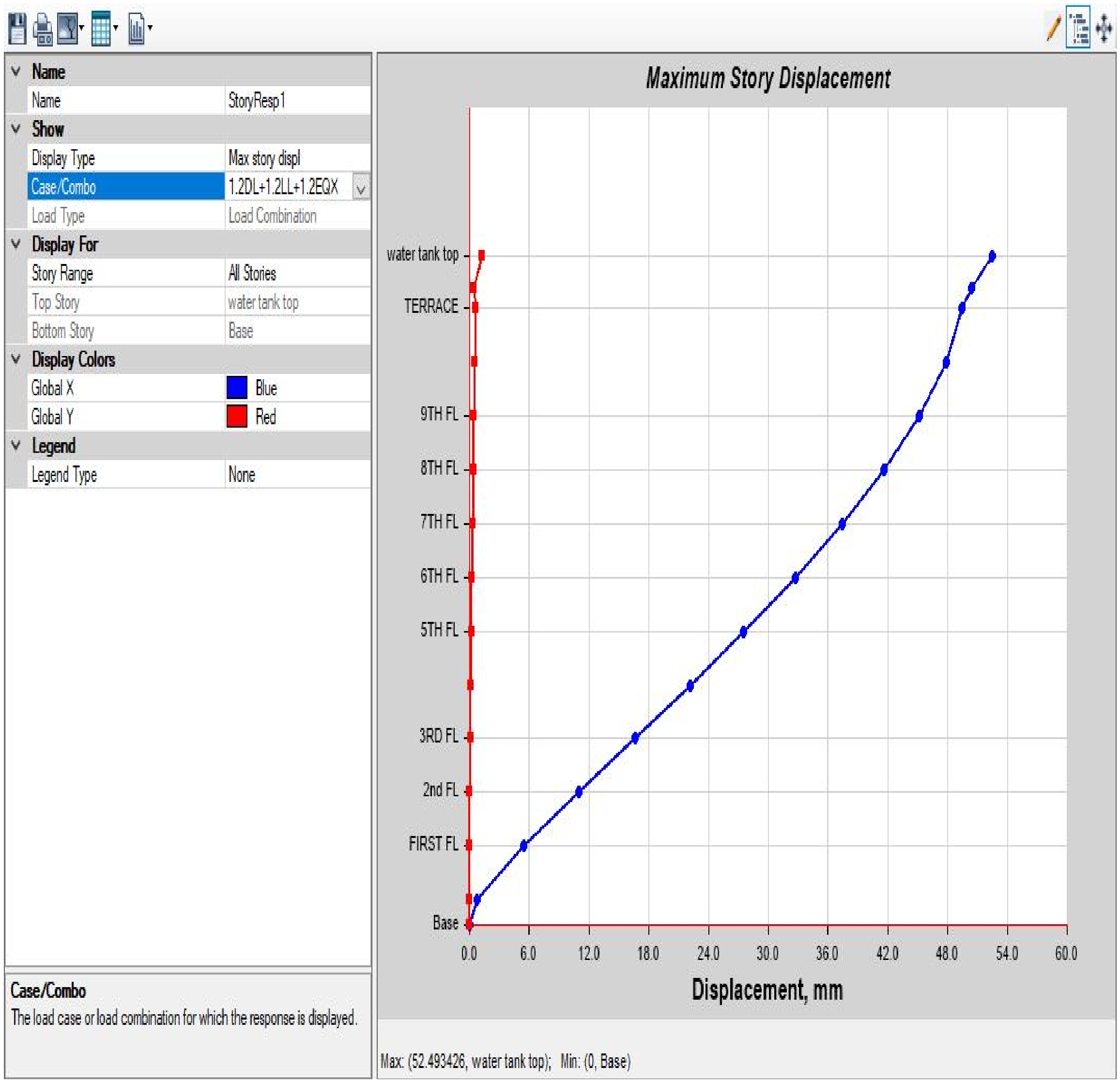


Figure 19: Maximum storey displacement of G+10 with Empty water tank in the direction of X for EQX

In this model, Maximum Storey Displacement is 52.493426mm at top of water tank in X-Direction.

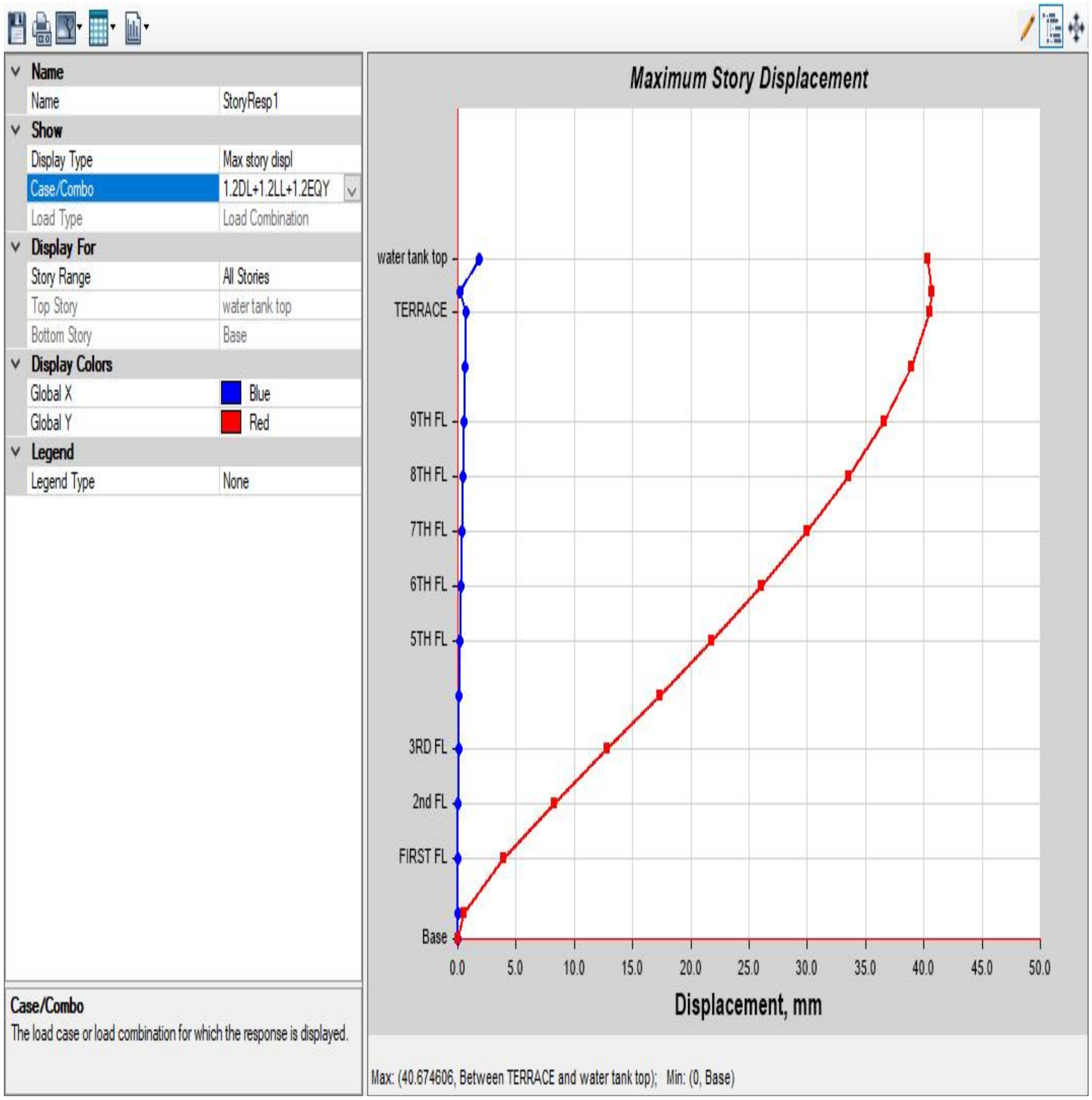


Figure 20: Maximum storey displacement of G+10 with Empty water tank in the direction of Y for EQY

In this model, Maximum Storey Displacement is 40.674606mm between terrace and top of water tank in Y- Direction.

1	TABLE: Modal Participating Mass Ratios														
2	Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
3			sec												
4	Modal	1	1.599	0.7665	0.00001144	0	0.7665	0.00001144	0	0.000006929	0.2288	0.0015	0.000006929	0.2288	0.0015
5	Modal	2	1.417	0.0001	0.7497	0	0.7666	0.7498	0	0.2372	0.000004636	0.0095	0.2372	0.2288	0.011
6	Modal	3	1.287	0.0014	0.0093	0	0.768	0.7591	0	0.0012	0.000002753	0.7594	0.2384	0.2288	0.7704
7	Modal	4	0.523	0.0946	0	0	0.8626	0.7591	0	0.000001362	0.44	0.0002	0.2384	0.6688	0.7706
8	Modal	5	0.456	0.00000577	0.0962	0	0.8626	0.8553	0	0.4158	0.0000235	0.0015	0.6543	0.6688	0.7721
9	Modal	6	0.42	0.0002	0.0016	0	0.8628	0.857	0	0.0067	0.0007	0.0886	0.661	0.6696	0.8607
10	Modal	7	0.301	0.0335	0	0	0.8963	0.857	0	0	0.0494	0.0001	0.661	0.719	0.8608
11	Modal	8	0.256	0.000002609	0.0347	0	0.8963	0.8917	0	0.0509	0.000005571	0.0011	0.7118	0.719	0.8619
12	Modal	9	0.242	0.0001	0.0011	0	0.8965	0.8929	0	0.0018	0.0004	0.0333	0.7136	0.7193	0.8952
13	Modal	10	0.208	0.0178	8.578E-07	0	0.9143	0.8929	0	0.000001953	0.0587	0.0001	0.7136	0.7781	0.8953
14	Modal	11	0.172	0.00000282	0.019	0	0.9143	0.9118	0	0.0585	0.000006264	0.0009	0.7721	0.7781	0.8963
15	Modal	12	0.164	0.0003	0.001	0	0.9146	0.9128	0	0.003	0.0006	0.0176	0.7751	0.7786	0.9139

Table 11: Modal participating mass ratio of G+10 with Empty water tank

1	TABLE: Base Reactions											
2	Output Case	Case Type	Step Type	FX	FY	FZ	MX	MY	MZ	X	Y	Z
3				kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
7	EQY	LinStatic		0	-2505.1501	0	67573.6823	0	-22529.6824	0	0	0
8	EQX	LinStatic		-2505.1501	0	0	0	-67573.6823	22563.0195	0	0	0
9	LIVE>5	LinStatic		0	0	0	0	0	0	0	0	0
10	WATER TANK PRESSURE	LinStatic		0	0	0	0	0	0	0	0	0
11	TH-X	NonModHist	Max	2117.7027	4.841	0	11.5862	41202.0627	-2.9829	0	0	0
12	TH-X	NonModHist	Min	0.3314	-4.1308	0	-11.9163	0	-19294.0265	0	0	0
13	TH-Y	NonModHist	Max	4.8937	2307.9005	0	0	21.6333	20650.4381	0	0	0
14	TH-Y	NonModHist	Min	-4.1757	0.335	0	-42287.4847	-18.7867	3.015	0	0	0
15	1.5DL	Combination		0	0	81182.0886	737290.1696	-723466.0459	0	0	0	0
16	1.5DL+1.5LL	Combination		0	0	97230.2136	881799.2321	-867823.2334	0	0	0	0
17	1.2DL+1.2LL+1.2EQY	Combination		0	-3006.1801	77784.1709	786527.8045	-694258.5867	-27035.6188	0	0	0
18	1.2DL+1.2LL-1.2EQY	Combination		0	3006.1801	77784.1709	624350.9668	-694258.5867	27035.6188	0	0	0
19	1.2DL+1.2LL+1.2EQX	Combination		-3006.1801	0	77784.1709	705439.3857	-775347.0055	27075.6234	0	0	0
20	1.2DL+1.2LL-1.2EQX	Combination		3006.1801	0	77784.1709	705439.3857	-613170.1679	-27075.6234	0	0	0
21	1.5DL+1.5EQY	Combination		0	-3757.7252	81182.0886	838650.6931	-723466.0459	-33794.5236	0	0	0
22	1.5DL-1.5EQY	Combination		0	3757.7252	81182.0886	635929.6461	-723466.0459	33794.5236	0	0	0
23	1.5DL+1.5EQX	Combination		-3757.7252	0	81182.0886	737290.1696	-824826.5694	33844.5292	0	0	0
24	1.5DL-1.5EQX	Combination		3757.7252	0	81182.0886	737290.1696	-622105.5224	-33844.5292	0	0	0
25	0.9DL+1.5EQY	Combination		0	-3757.7252	48709.2532	543734.6253	-434079.6275	-33794.5236	0	0	0
26	0.9DL-1.5EQY	Combination		0	3757.7252	48709.2532	341013.5782	-434079.6275	33794.5236	0	0	0
27	0.9DL+1.5EQX	Combination		-3757.7252	0	48709.2532	442374.1017	-535440.1511	33844.5292	0	0	0
28	0.9DL-1.5EQX	Combination		3757.7252	0	48709.2532	442374.1017	-332719.104	-33844.5292	0	0	0
29	DL+LL	Combination		0	0	64820.1424	587866.1547	-578548.8223	0	0	0	0

Table12: Base reactions of the G+10 model with Empty water tank

Modeling and analysis of G+10 model with Filled Water tank

Tank Dimensions :

Length = 3m

Width = 3m

Height = 2m

Liquid Mass = 20kN

Water pressure on wall = H x Density of water
= 2m x 20kN/m^3
= 40 kN/m^2

Calculation for 20 thousand liter water tank :

Capacity of tank = 20000 liter

Tank Area = 3m x 3m = 9m^2

So, 20000 liter = 200kN

Water load at bottom = 200/9 = 22.22kN/m

When water load is half = 22.22/2
=11.11kN/m^2

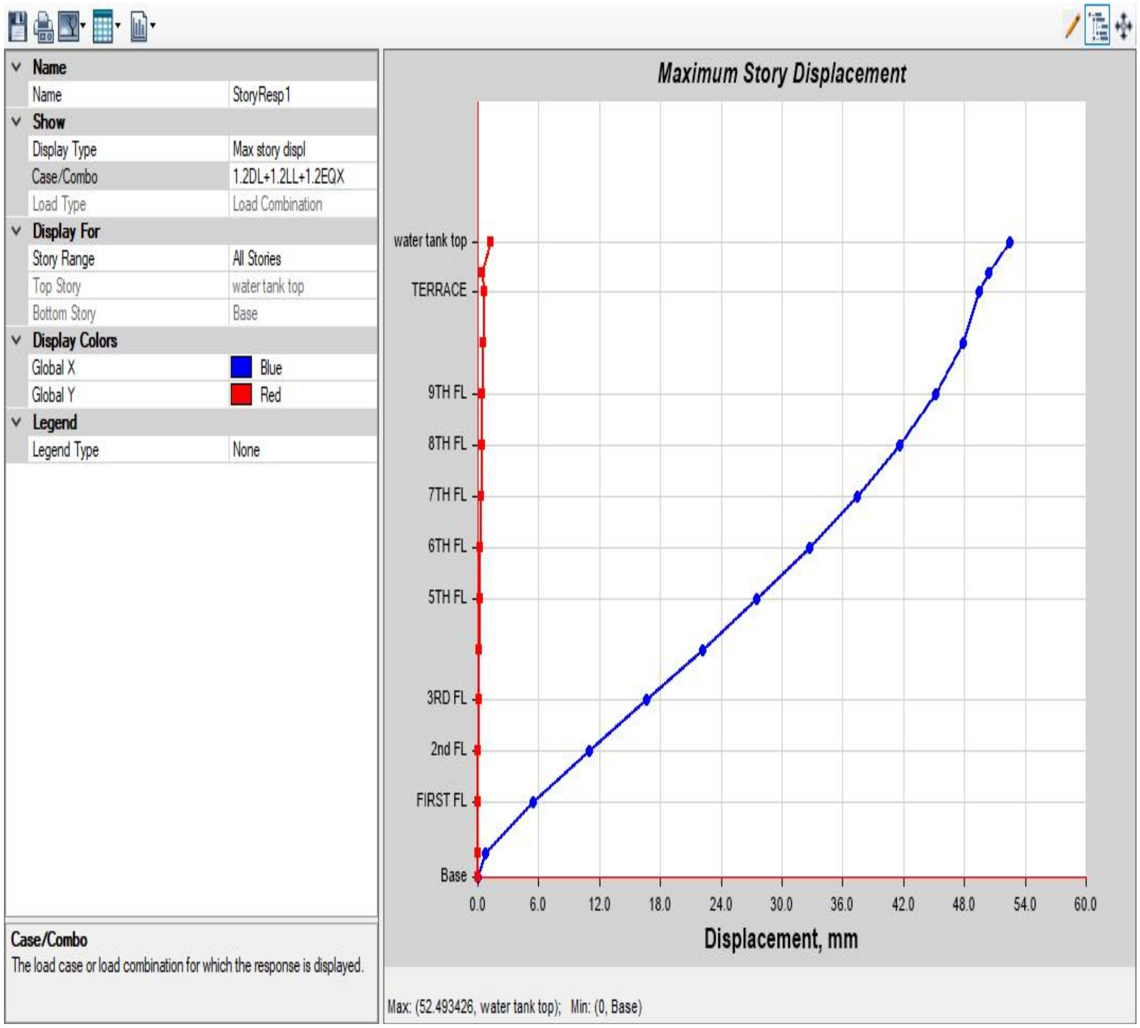


Figure 21: Maximum storey displacement of G+10 with filled water tank in the direction of X for EQX

In this model, Maximum Storey Displacement is 52.493426mm at top of water tank in X-Direction.

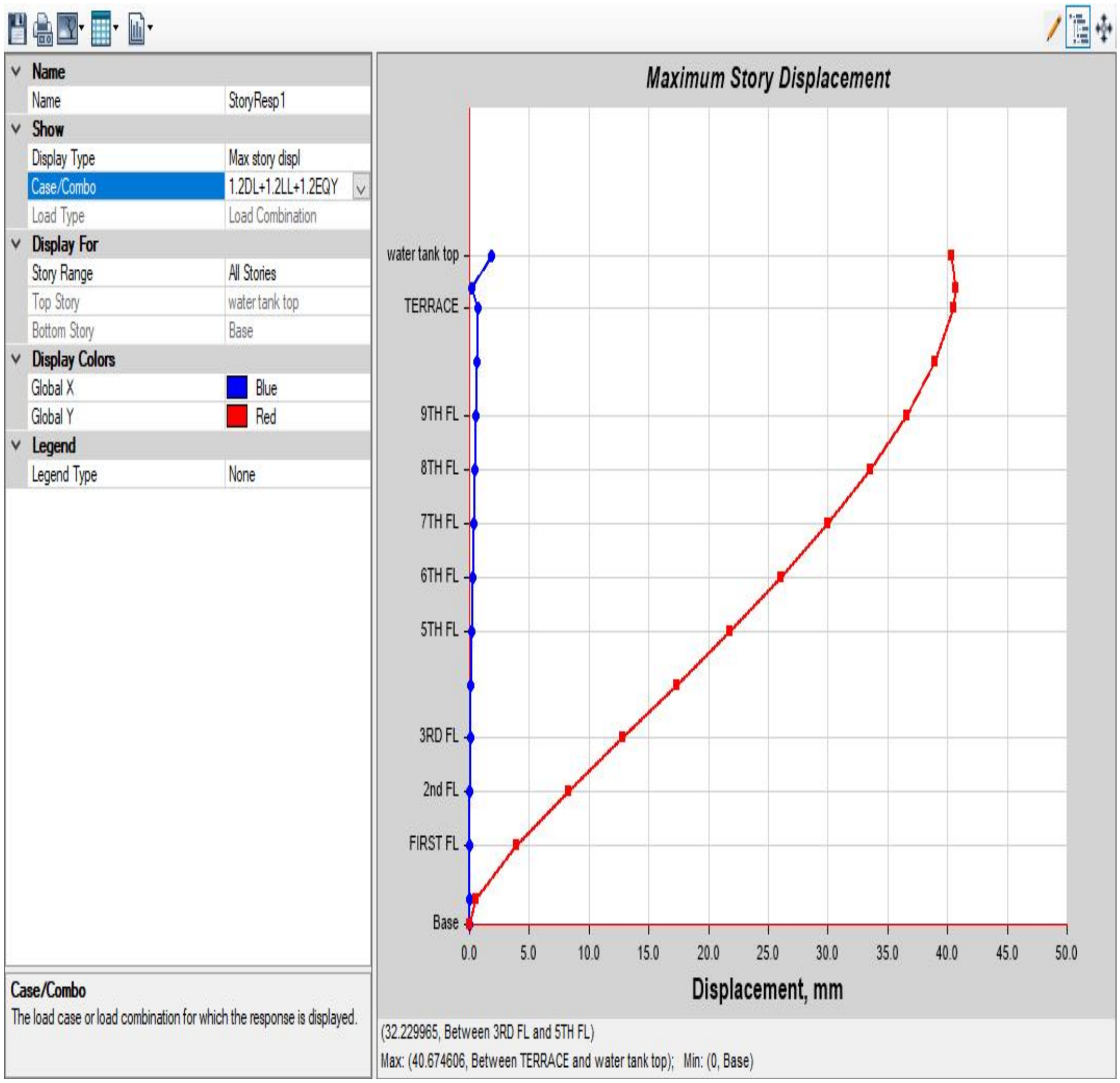


Figure 22: Maximum storey displacement of G+10 with filled water tank in the direction of Y for EQY

In this model, Maximum Storey Displacement is 40.674606mm between terrace and top of water tank in Y- Direction

TABLE: Modal Participating Mass Ratios

Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
		sec												
Modal	1	1.602	0.7661	0.0000197	0	0.7661	0.0000197	0	0.00001189	0.2288	0.002	0.00001189	0.2288	0.002
Modal	2	1.42	0.0001	0.747	0	0.7662	0.747	0	0.2369	0.000008151	0.0124	0.2369	0.2288	0.0143
Modal	3	1.29	0.0019	0.0121	0	0.768	0.7591	0	0.0016	0.00000443	0.7562	0.2385	0.2288	0.7705
Modal	4	0.524	0.0946	6.076E-07	0	0.8626	0.7591	0	0.000002403	0.4398	0.0003	0.2385	0.6686	0.7708
Modal	5	0.457	0.00001003	0.0958	0	0.8626	0.8549	0	0.4137	0.00004107	0.002	0.6522	0.6686	0.7727
Modal	6	0.421	0.0003	0.0021	0	0.8629	0.857	0	0.0087	0.001	0.088	0.6609	0.6696	0.8608
Modal	7	0.302	0.0335	0	0	0.8964	0.857	0	0	0.0494	0.0001	0.6609	0.719	0.8609
Modal	8	0.257	0.000004682	0.0344	0	0.8964	0.8914	0	0.0505	0.000009855	0.0014	0.7114	0.719	0.8623
Modal	9	0.242	0.0002	0.0015	0	0.8966	0.8929	0	0.0023	0.0005	0.0329	0.7137	0.7195	0.8953
Modal	10	0.208	0.0178	0.000001356	0	0.9143	0.8929	0	0.000003056	0.0586	0.0002	0.7137	0.7781	0.8954
Modal	11	0.172	0.000005287	0.0186	0	0.9143	0.9115	0	0.0575	0.00001197	0.0012	0.7712	0.7781	0.8967
Modal	12	0.165	0.0004	0.0013	0	0.9147	0.9128	0	0.0039	0.0007	0.0172	0.7751	0.7789	0.9139

Table13: Modal participating mass ratio of G+10 with filled water tank

TABLE: Base Reactions

Output Case	Case Type	Step Type	FX	FY	FZ	MX	MY	MZ	X	Y	Z
			kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
Dead	LinStatic		0	0	30419.8924	276748.5297	-270677.9473	0	0	0	0
Live	LinStatic		0	0	10698.75	96339.375	-96238.125	0	0	0	0
SIDL	LinStatic		0	0	23701.5	214778.25	-211632.75	0	0	0	0
EQY	LinStatic		0	-2505.1501	0	67573.6823	0	-22529.6824	0	0	0
EQX	LinStatic		-2505.1501	0	0	0	-67573.6823	22563.0195	0	0	0
LIVE>5	LinStatic		0	0	180	2970	-270	0	0	0	0
WATER TANK PRESSURE	LinStatic		0	0	0	0	0	0	0	0	0
TH-X	NonModHist	Max	2119.8575	6.0498	0	15.4005	41290.7602	-2.9829	0	0	0
TH-X	NonModHist	Min	0.3314	-5.1809	0	-15.5386	0	-19338.8525	0	0	0
TH-Y	NonModHist	Max	6.1151	2309.1316	0	0	27.8214	20642.2829	0	0	0
TH-Y	NonModHist	Min	-5.2369	0.335	0	-42446.7338	-23.4964	3.015	0	0	0
1.5DL	Combination		0	0	81182.0886	737290.1696	-723466.0459	0	0	0	0
1.5DL+1.5LL	Combination		0	0	97500.2136	886254.2321	-868228.2334	0	0	0	0
1.2DL+1.2LL+1.2EQY	Combination		0	-3006.1801	78000.1709	790091.8045	-694582.5867	-27035.6188	0	0	0
1.2DL+1.2LL-1.2EQY	Combination		0	3006.1801	78000.1709	627914.9668	-694582.5867	27035.6188	0	0	0
1.2DL+1.2LL+1.2EQX	Combination		-3006.1801	0	78000.1709	709003.3857	-775671.0055	27075.6234	0	0	0
1.2DL+1.2LL-1.2EQX	Combination		3006.1801	0	78000.1709	709003.3857	-613494.1679	-27075.6234	0	0	0
1.5DL+1.5EQY	Combination		0	-3757.7252	81182.0886	838650.6931	-723466.0459	-33794.5236	0	0	0
1.5DL-1.5EQY	Combination		0	3757.7252	81182.0886	635929.6461	-723466.0459	33794.5236	0	0	0
1.5DL+1.5EQX	Combination		-3757.7252	0	81182.0886	737290.1696	-824826.5694	33844.5292	0	0	0
1.5DL-1.5EQX	Combination		3757.7252	0	81182.0886	737290.1696	-622105.5224	-33844.5292	0	0	0
0.9DL+1.5EQY	Combination		0	-3757.7252	48709.2532	543734.6253	-434079.6275	-33794.5236	0	0	0
0.9DL-1.5EQY	Combination		0	3757.7252	48709.2532	341013.5782	-434079.6275	33794.5236	0	0	0
0.9DL+1.5EQX	Combination		-3757.7252	0	48709.2532	442374.1017	-535440.1511	33844.5292	0	0	0
0.9DL-1.5EQX	Combination		3757.7252	0	48709.2532	442374.1017	-332719.104	-33844.5292	0	0	0
DL+LL	Combination		0	0	65000.1424	590836.1547	-578818.8223	0	0	0	0

Table 14: Base reactions of G+10 model with Filled water tank

Modeling and analysis of G+10 model with Half Filled Water tank

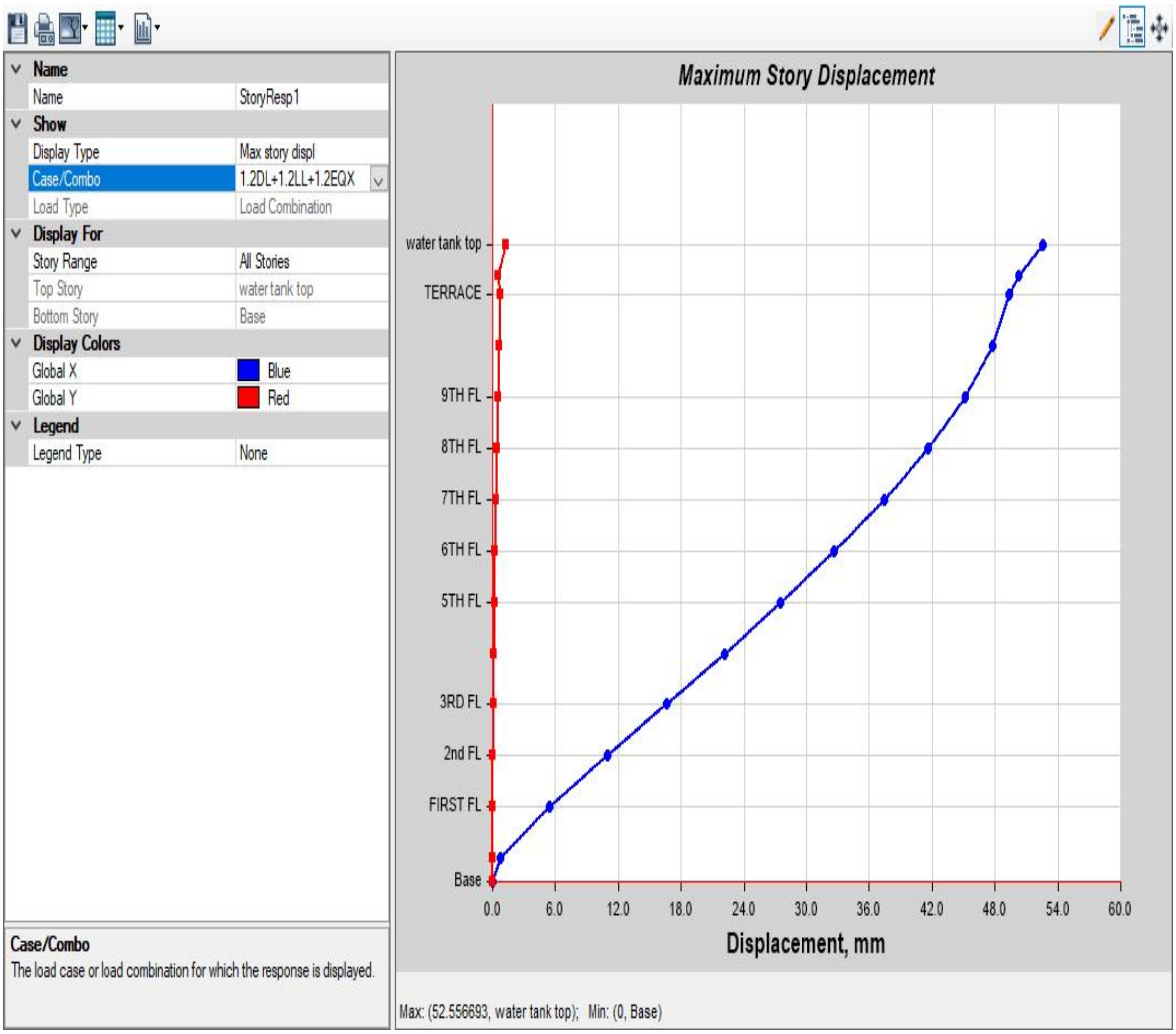


Figure 23: Maximum storey displacement of G+10 with Half filled water tank in the direction of X for EQX

In this model, Maximum Storey Displacement is 52.556693mm at top of water tank in X-Direction

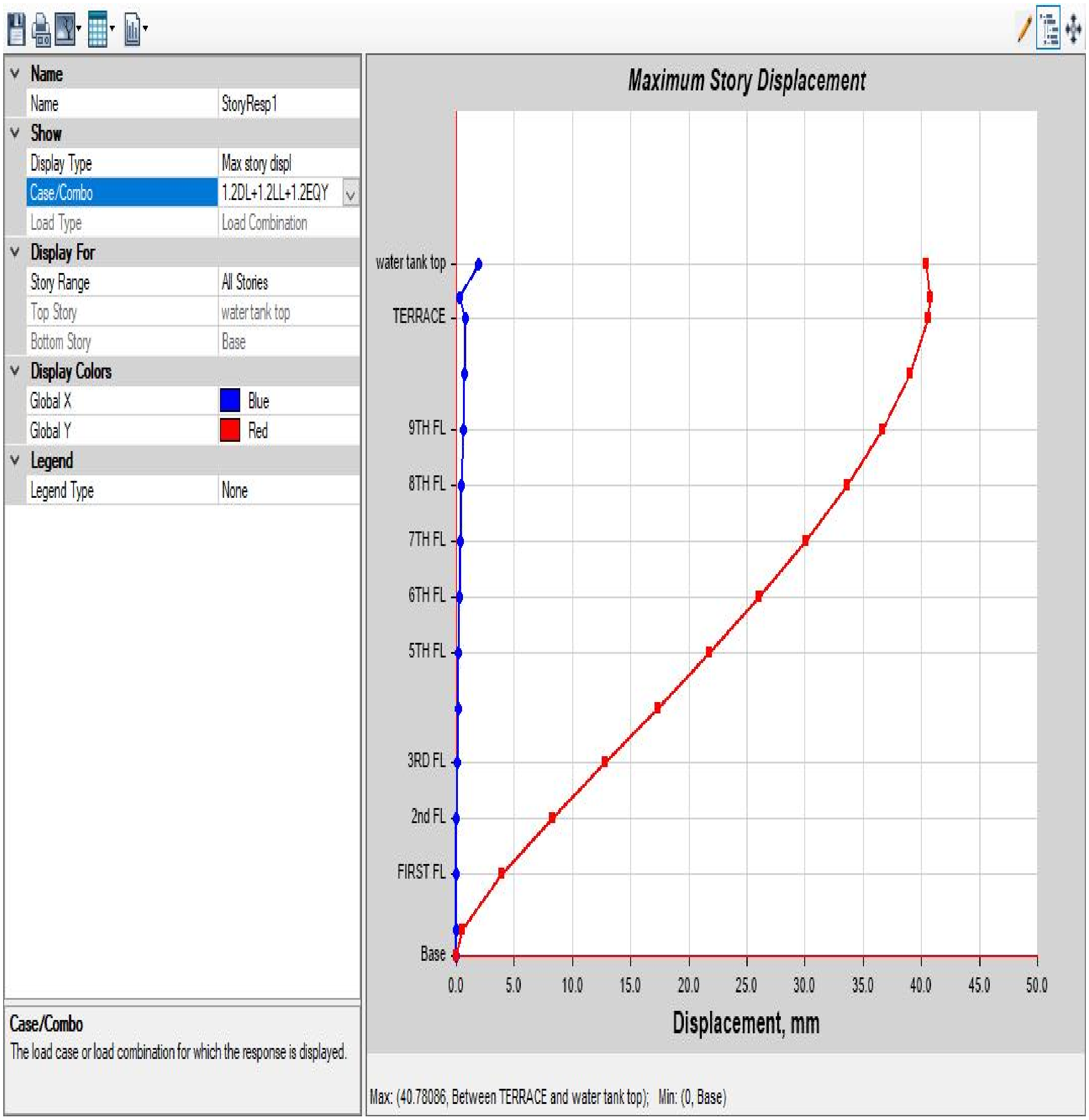


Figure 24: Maximum storey displacement of G+10 with Half filled water tank in the direction of Y for EQY

In this model, Maximum Storey Displacement is 40.78086mm between terrace and top of water tank in Y- Direction

1	TABLE: Modal Participating Mass Ratios														
2	Case	Mode	Period	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY	SumRZ
3			sec												
4	Modal	1	1.601	0.7663	0.00001515	0	0.7663	0.00001515	0	0.000009162	0.2288	0.0017	0.000009162	0.2288	0.0017
5	Modal	2	1.419	0.0001	0.7484	0	0.7664	0.7484	0	0.2371	0.000006207	0.0109	0.2371	0.2288	0.0126
6	Modal	3	1.289	0.0016	0.0107	0	0.768	0.7591	0	0.0014	0.000003533	0.7578	0.2385	0.2288	0.7704
7	Modal	4	0.523	0.0946	0	0	0.8626	0.7591	0	0.000001828	0.4399	0.0002	0.2385	0.6687	0.7707
8	Modal	5	0.457	0.000007686	0.096	0	0.8626	0.8551	0	0.4148	0.00003138	0.0017	0.6533	0.6687	0.7724
9	Modal	6	0.42	0.0002	0.0019	0	0.8628	0.857	0	0.0077	0.0008	0.0883	0.661	0.6696	0.8607
10	Modal	7	0.302	0.0335	0	0	0.8963	0.857	0	0	0.0494	0.0001	0.661	0.719	0.8609
11	Modal	8	0.257	0.000003538	0.0346	0	0.8964	0.8916	0	0.0507	0.000007499	0.0013	0.7116	0.719	0.8621
12	Modal	9	0.242	0.0002	0.0013	0	0.8965	0.8929	0	0.002	0.0004	0.0331	0.7137	0.7194	0.8952
13	Modal	10	0.208	0.0178	0.000001087	0	0.9143	0.8929	0	0.000002462	0.0587	0.0001	0.7137	0.7781	0.8954
14	Modal	11	0.172	0.000003918	0.0188	0	0.9143	0.9117	0	0.058	0.000008791	0.0011	0.7717	0.7781	0.8964
15	Modal	12	0.165	0.0003	0.0011	0	0.9146	0.9128	0	0.0034	0.0006	0.0174	0.7751	0.7788	0.9139

Table 15: Modal participating mass ratio of G+10 with Half filled water tank

1	TABLE: Base Reactions											
2	Output Case	Case Type	Step Type	FX	FY	FZ	MX	MY	MZ	X	Y	Z
3				kN	kN	kN	kN-m	kN-m	kN-m	m	m	m
4	Dead	LinStatic		0	0	30419.8924	276748.5297	-270677.9473	0	0	0	0
5	Live	LinStatic		0	0	10698.75	96339.375	-96238.125	0	0	0	0
6	SIDL	LinStatic		0	0	23701.5	214778.25	-211632.75	0	0	0	0
7	EQY	LinStatic		0	-2505.1501	0	67573.6823	0	-22529.6824	0	0	0
8	EQX	LinStatic		-2505.1501	0	0	0	-67573.6823	22563.0195	0	0	0
9	LIVE>5	LinStatic		0	0	90	1485	-135	0	0	0	0
10	WATER TANK PRESSURE	LinStatic		0	0	0	0	0	0	0	0	0
11	TH-X	NonModHist	Max	2118.7646	5.4405	0	13.3374	41246.3325	-2.9829	0	0	0
12	TH-X	NonModHist	Min	0.3314	-4.6509	0	-13.6683	0	-19316.5777	0	0	0
13	TH-Y	NonModHist	Max	5.4996	2308.5092	0	0	24.6554	20646.536	0	0	0
14	TH-Y	NonModHist	Min	-4.7013	0.335	0	-42366.973	-21.1149	3.015	0	0	0
15	1.5DL	Combination		0	0	81182.0886	737290.1696	-723466.0459	0	0	0	0
16	1.5DL+1.5LL	Combination		0	0	97365.2136	884026.7321	-868025.7334	0	0	0	0
17	1.2DL+1.2LL+1.2EQY	Combination		0	-3006.1801	77892.1709	788309.8045	-694420.5867	-27035.6188	0	0	0
18	1.2DL+1.2LL-1.2EQY	Combination		0	3006.1801	77892.1709	626132.9668	-694420.5867	27035.6188	0	0	0
19	1.2DL+1.2LL+1.2EQX	Combination		-3006.1801	0	77892.1709	707221.3857	-775509.0055	27075.6234	0	0	0
20	1.2DL+1.2LL-1.2EQX	Combination		3006.1801	0	77892.1709	707221.3857	-613332.1679	-27075.6234	0	0	0
21	1.2DL+1.2EQY	Combination		0	-3757.7252	81182.0886	838650.6931	-723466.0459	-33794.5236	0	0	0
22	1.5DL-1.5EQY	Combination		0	3757.7252	81182.0886	635929.6461	-723466.0459	33794.5236	0	0	0
23	1.5DL+1.5EQX	Combination		-3757.7252	0	81182.0886	737290.1696	-824826.5694	33844.5292	0	0	0
24	1.5DL-1.5EQX	Combination		3757.7252	0	81182.0886	737290.1696	-622105.5224	-33844.5292	0	0	0
25	0.9DL+1.5EQY	Combination		0	-3757.7252	48709.2532	543734.6253	-434079.6275	-33794.5236	0	0	0
26	0.9DL-1.5EQY	Combination		0	3757.7252	48709.2532	341013.5782	-434079.6275	33794.5236	0	0	0
27	0.9DL+1.5EQX	Combination		-3757.7252	0	48709.2532	442374.1017	-535440.1511	33844.5292	0	0	0
28	0.9DL-1.5EQX	Combination		3757.7252	0	48709.2532	442374.1017	-332719.104	-33844.5292	0	0	0
29	DL+LL	Combination		0	0	64910.1424	589351.1547	-578683.8223	0	0	0	0

Table 16: Base reactions of G+10 with Half filled water tank

Modeling of G+14 model without Water tank & With Water tank using Time history analysis

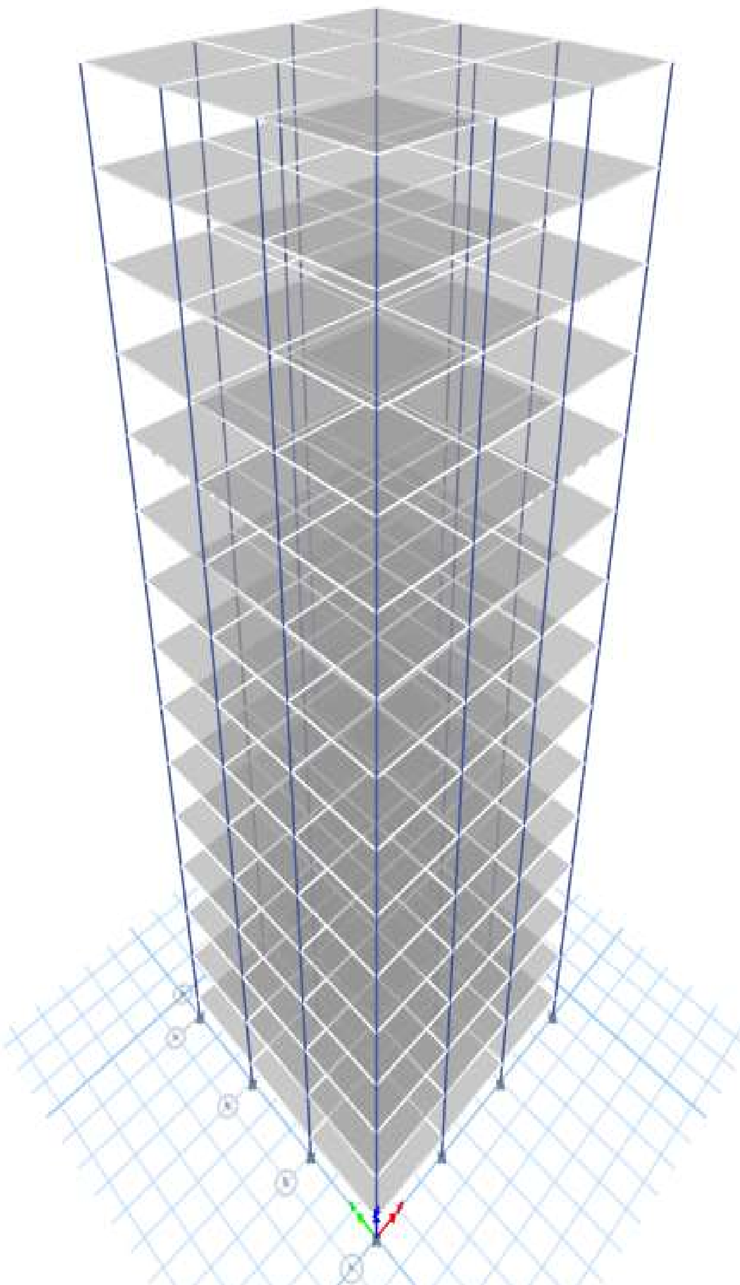


Figure 25 : 3D View of G+14 Model without water tank

TIME PERIOD

Time period = $0.075\ h^{0.75}$
$= 0.075\ (51)^{0.75}$

Time period = 1.4313 Seconds

Tank Dimensions :

Length = 3m

Width = 3m

Height = 2m

Liquid Mass = 30kN

Water pressure on wall = H x Density of water
= 2m x 30kN/m^3
= 60 kN/m^2

Calculation for 30 thousand liter water tank :

Capacity of tank = 30000 liter

Tank Area = 3m x 3m = 9m^2

So, 30000 liter = 300kn

Water load at bottom = 300/9 = 33.33kN/m

When water load is Half = 33.3/2
=16.65kN/m^2

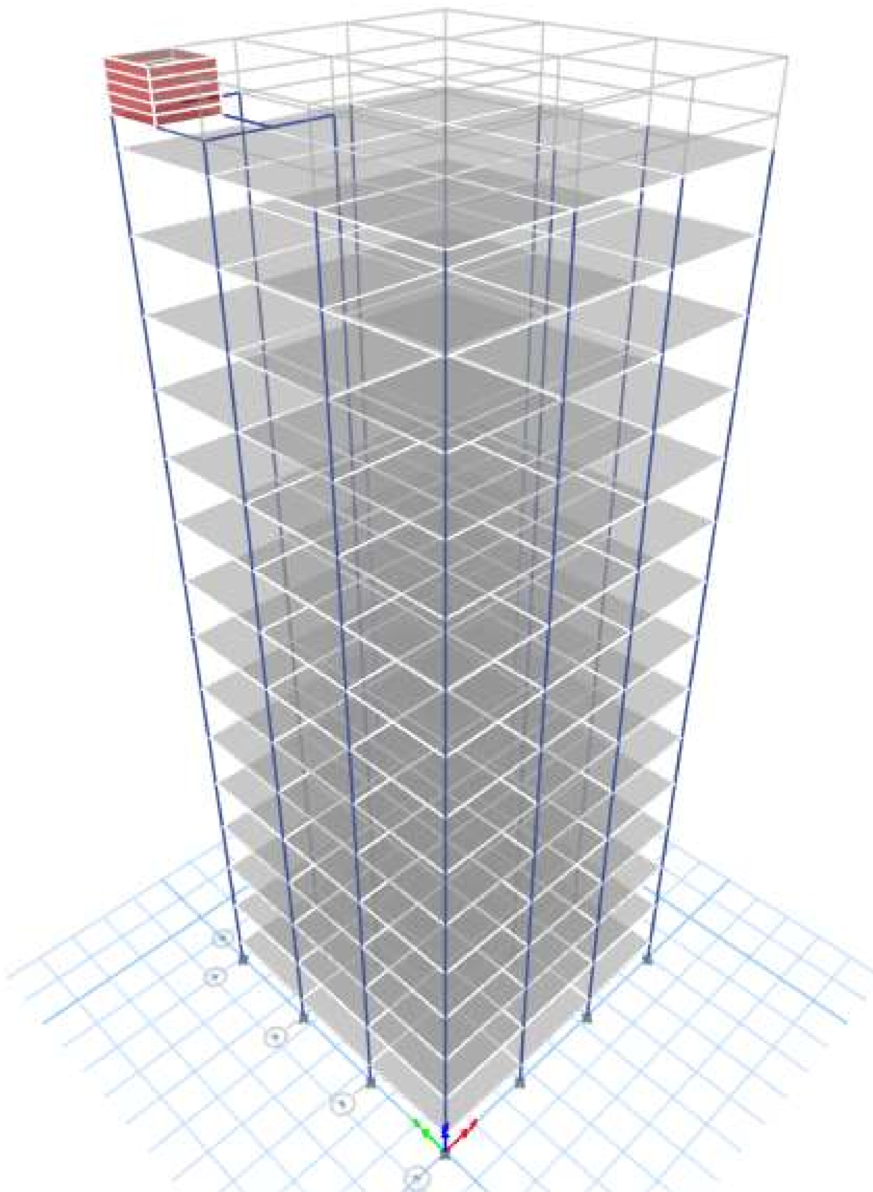


Figure 26: 3D view of G+14 model with tank of Empty, filled & Half water Depth

Analysis of G+14 model without Water tank & With Water tank using Time history analysis

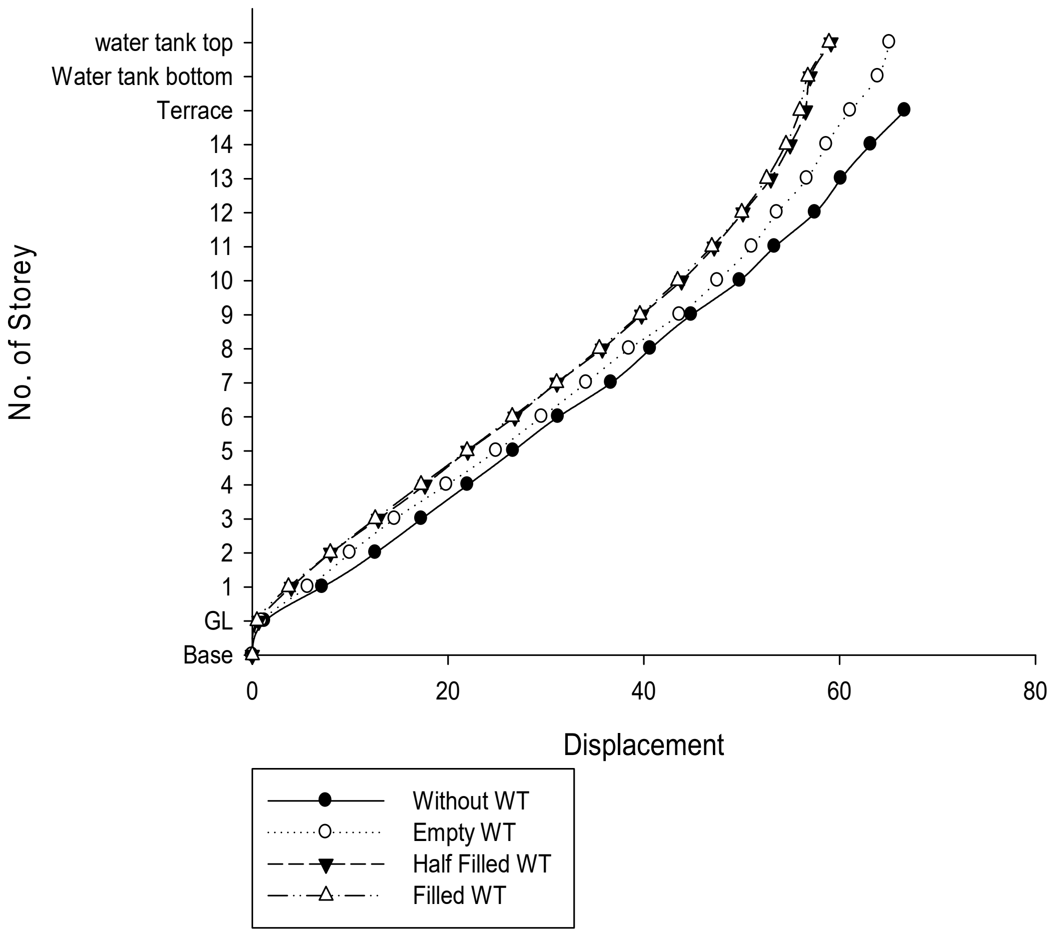


Figure 27: Maximum displacement for G+14 in the direction of X for EQX

No. of Storey	Without WT	Empty WT	Half filled WT	Filled WT
Base	0	0	0	0
GL	1.283	0.986	0.668	0.484
1	7.17	5.698	3.989	3.696
2	12.59	10.011	8.011	7.969
3	17.298	14.569	12.889	12.559
4	22.016	19.869	17.641	17.243
5	26.688	24.953	22.016	21.931
6	31.261	29.595	26.832	26.562
7	36.681	34.133	31.121	31.09
8	40.681	38.512	35.753	35.456
9	44.885	43.67	39.771	39.6
10	49.807	47.54	43.845	43.454
11	53.375	51.051	47.191	46.947
12	57.51	53.624	50.121	50.002
13	60.137	56.684	52.971	52.542
14	63.191	58.673	54.946	54.511
Terrace	66.68	61.111	56.51	55.93
Water tank bottom		63.932	56.996	56.747
water tank top		65.116	59.124	58.912

Table 17: Maximum Displacement values of G+14 structure for different stories in the direction of X for EQX (In MM)

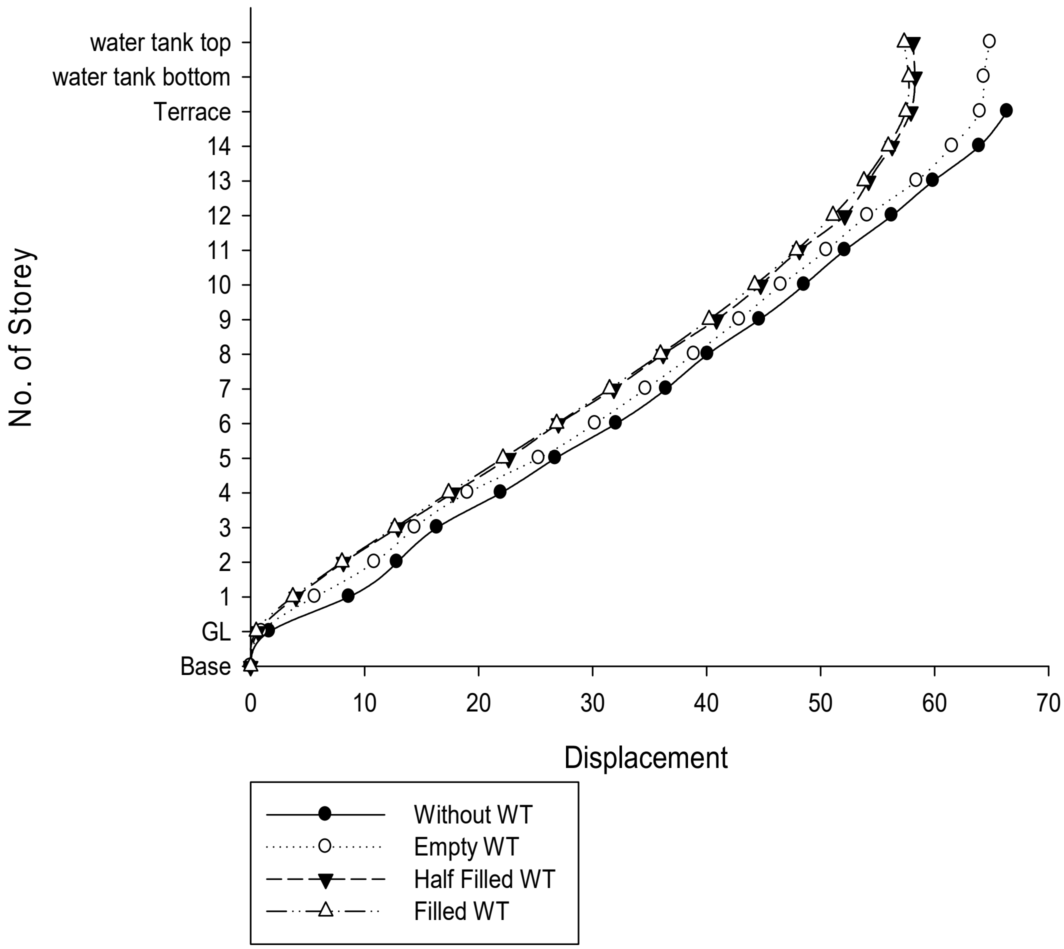


Figure 28: Maximum displacement for G+14 in the direction of Y for EQY

No. of Stories	Without WT	Empty WT	Half filled WT	Filled WT
Base	0	0	0	0
GL	1.659	0.976	0.682	0.485
1	8.642	5.652	3.989	3.711
2	12.85	10.878	8.15	8.011
3	16.369	14.42	12.948	12.643
4	21.97	19.052	17.763	17.382
5	26.752	25.3	22.642	22.14
6	32.078	30.24	27.011	26.855
7	36.462	34.674	31.868	31.48
8	40.112	38.916	36.191	35.958
9	44.648	42.895	40.875	40.227
10	48.565	46.533	44.746	44.221
11	52.134	50.533	48.147	47.867
12	56.272	54.119	52.133	51.087
13	59.894	58.445	54.219	53.802
14	63.928	61.553	56.284	55.94
Terrace	66.376	64.011	57.927	57.481
water tank bottom		64.344	58.282	57.734
water tank top		64.886	58.121	57.339

Table 18: Maximum Displacement values of G+14 structure for different stories in the direction of Y for EQY (In MM)

Modeling of G+18 model without Water tank & With Water tank using Time history analysis

In this structure we have add Shear walls and Diaphragms

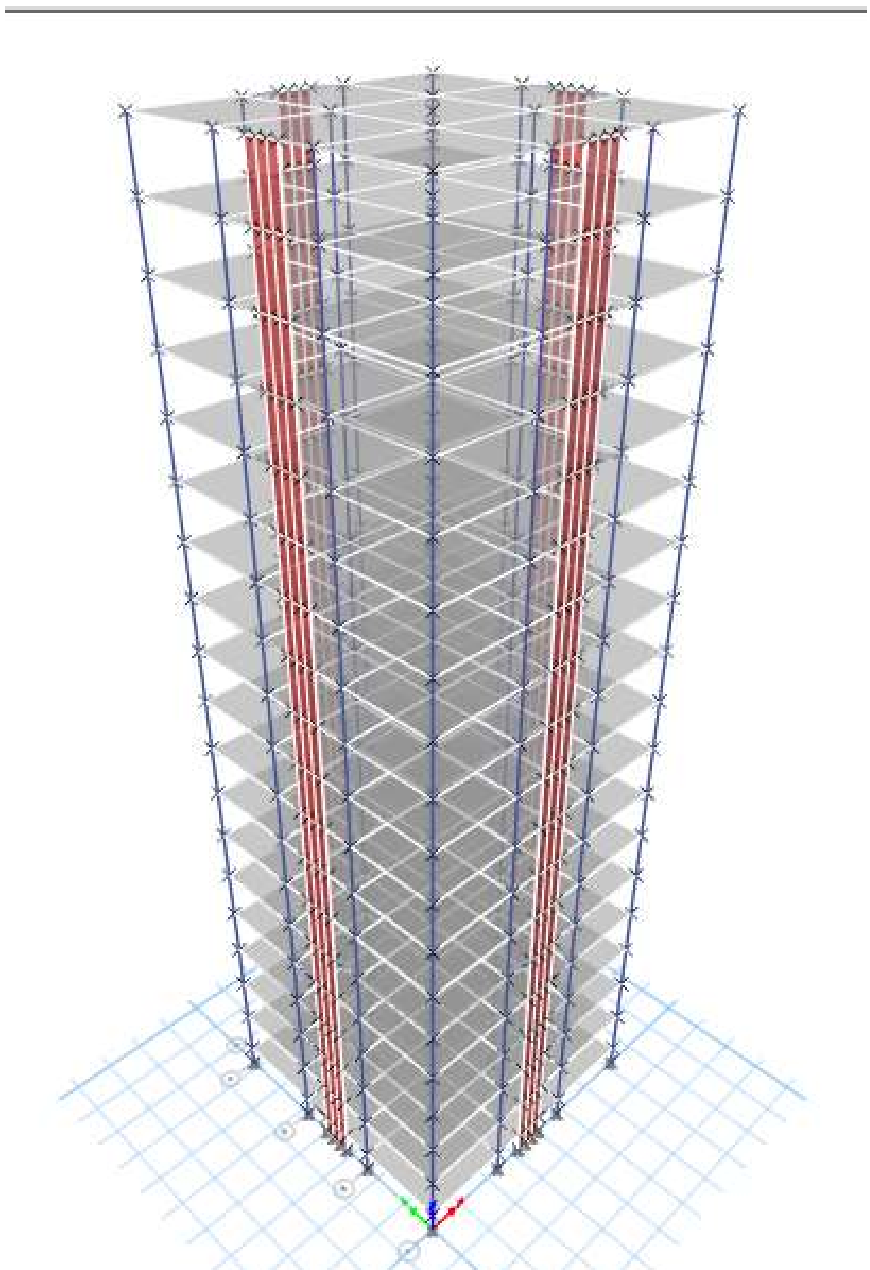


Figure 29: 3D view of G+18 model without water tank

TIME PERIOD

Time period = $0.075\ h^{0.75}$
$= 0.075\ (16.5)^{0.75}$

Time period = 1.701 Seconds

Tank Dimensions :

Length = 3m

Width = 6m

Height = 3m

Liquid Mass = 40kN

Water pressure on wall = H x Density of water
= 3m x 40kN/m^3
= 120 kN/m^2

Calculation for 40 thousand liter water tank :

Capacity of tank = 40000 liter

Tank Area = 3m x 6m = 18m^2

So, 40000 liter = 400kN

Water load at bottom = 400/18 = 22.22kN/m

When water load is Half = 22.2/2
=11.1kN/m^2

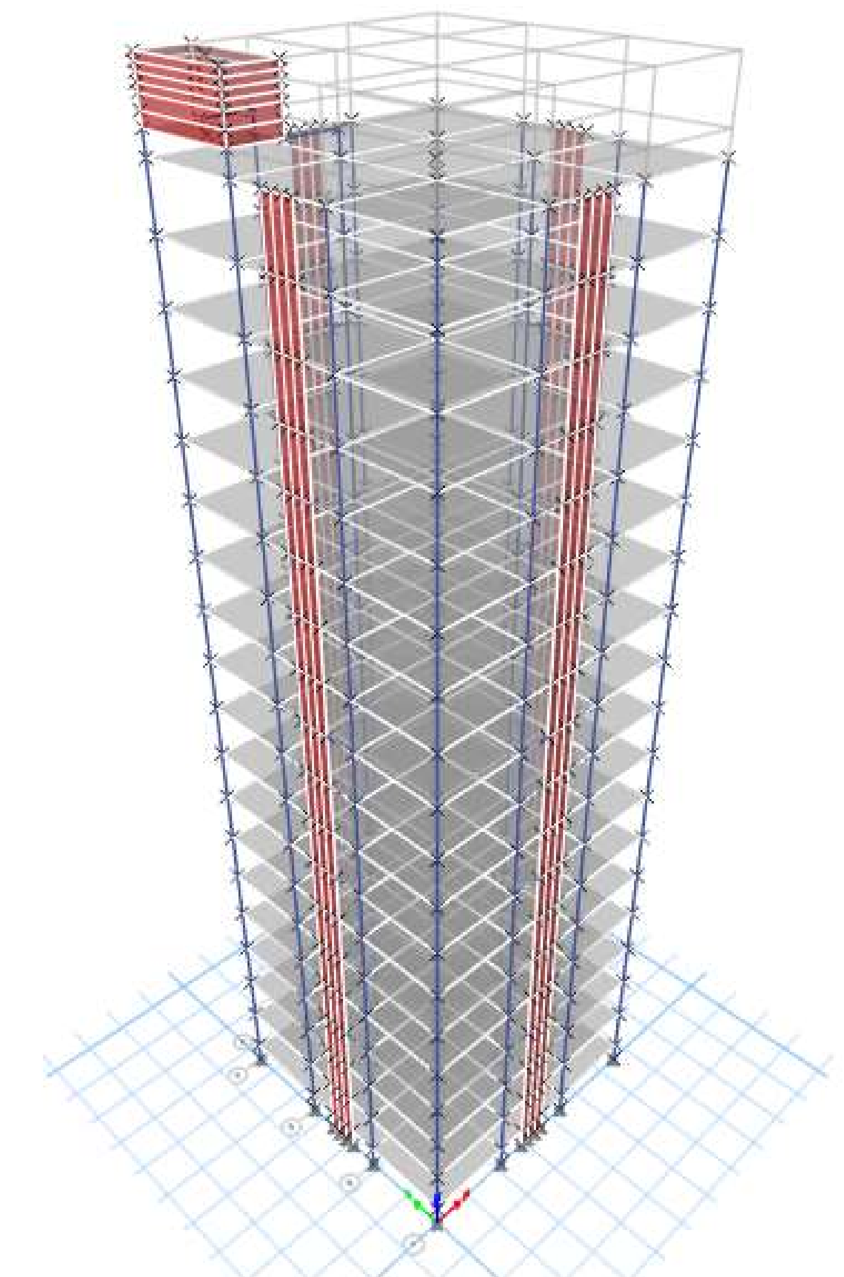


Figure 30: 3D view of G+18 model with tank of Empty, filled & Half water Depth

Analysis of G+18 model without Water tank & With Water tank using Time history analysis

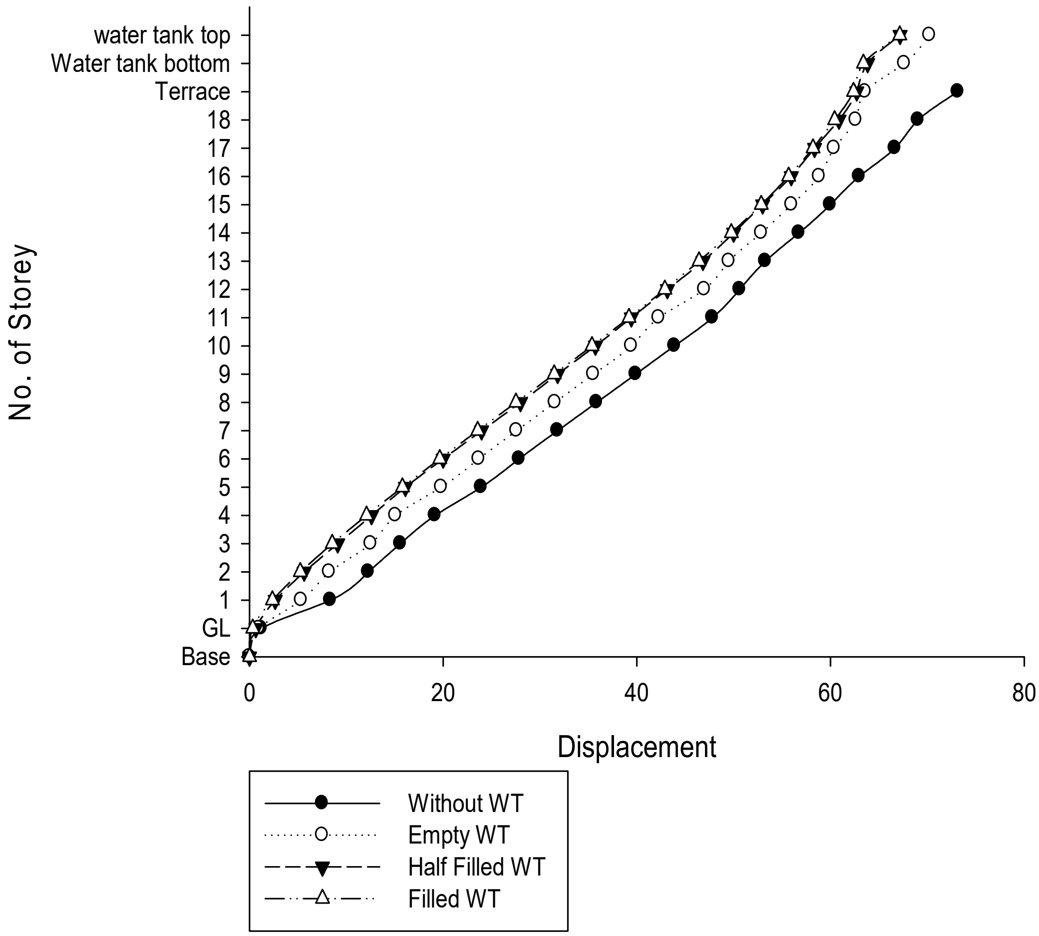


Figure 31: Maximum displacement for G+18 in the direction of X for EQX

No. of Storey	Without WT	Empty WT	Half Filled WT	Filled WT
Base	0	0	0	0
GL	1.228	0.961	0.659	0.327
1	8.37	5.363	2.66	2.361
2	12.277	8.254	5.648	5.25
3	15.595	12.549	9.11	8.541
4	19.174	15.096	12.612	12.083
5	23.939	19.821	16.1	15.801
6	27.838	23.67	19.998	19.643
7	31.825	27.6	23.972	23.563
8	35.857	31.566	27.986	27.519
9	39.894	35.528	31.829	31.47
10	43.894	39.446	35.724	35.374
11	47.819	42.278	39.433	39.192
12	50.628	46.986	43.15	42.886
13	53.283	49.533	46.834	46.416
14	56.748	52.88	49.992	49.746
15	59.987	55.991	52.989	52.839
16	62.966	58.835	55.945	55.664
17	66.659	60.384	58.361	58.194
18	69.046	62.622	60.867	60.413
Terrace	73.157	63.588	62.704	62.362
Water tank bottom		67.634	63.826	63.394
water tank top		70.239	67.188	67.15

Table 19: Maximum Displacement values of G+18 structure for different stories in the direction of X for EQX (In MM)

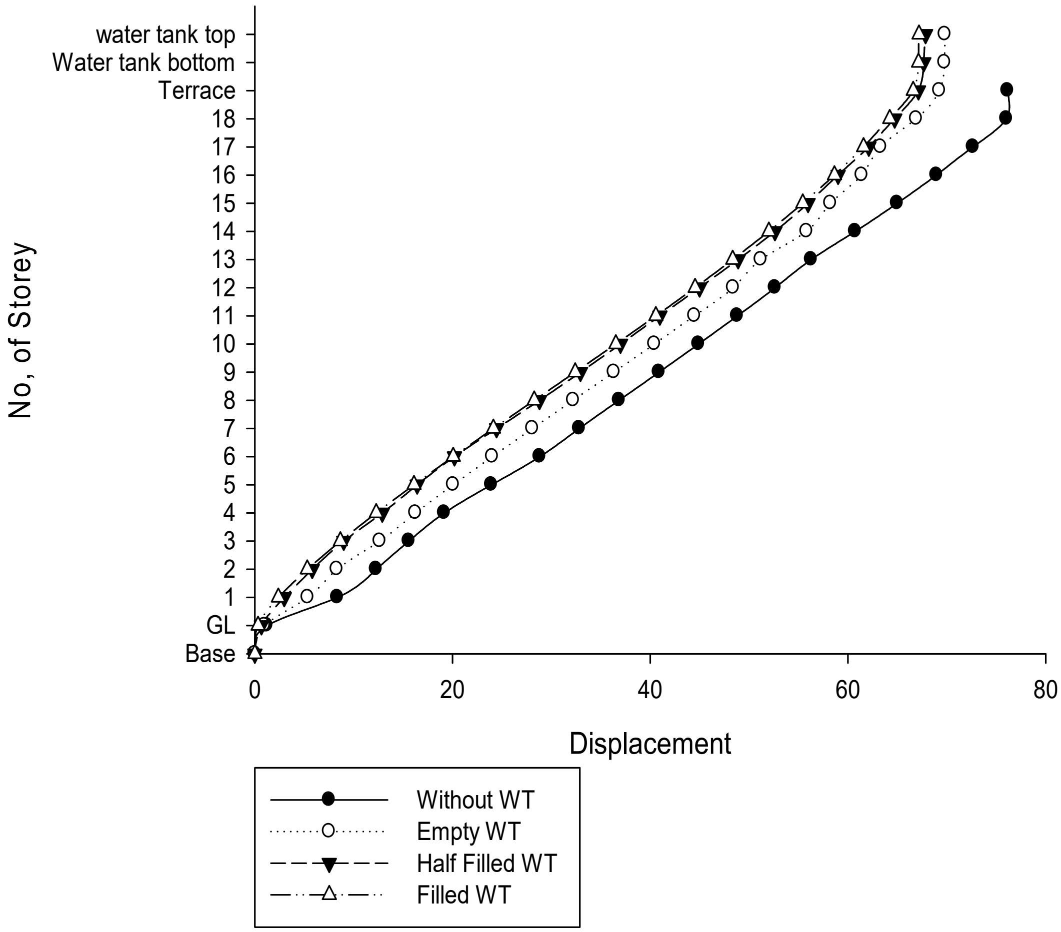


Figure 32: Maximum displacement for G+18 in the direction of Y for EQY

No. of Storey	Without WT	Empty WT	Half filled WT	Filled WT
Base	0	0	0	0
GL	1.235	0.986	0.679	0.329
1	8.37	5.381	2.984	2.383
2	12.277	8.308	5.815	5.312
3	15.595	12.655	8.996	8.663
4	19.174	16.272	12.896	12.286
5	23.939	20.085	16.422	16.107
6	28.838	24.042	20.193	20.072
7	32.825	28.097	24.466	24.138
8	36.857	32.208	28.798	28.261
9	40.894	36.335	32.947	32.401
10	44.894	40.437	36.995	36.518
11	48.819	44.475	40.983	40.574
12	52.628	48.41	44.989	44.529
13	56.283	51.207	48.886	48.347
14	60.748	55.828	52.608	51.993
15	64.987	58.239	55.965	55.431
16	68.966	61.41	58.997	58.631
17	72.659	63.313	62.102	61.568
18	76.046	66.925	64.721	64.217
Terrace	76.157	69.27	67.137	66.604
Water tank bottom		69.786	67.672	67.131
water tank top		69.81	67.853	67.188

Table 20: Maximum Displacement values of G+18 structure for different stories in the direction of Y for EQY (In MM)

Modeling of G+22 model without Water tank & With Water tank using Time history analysis

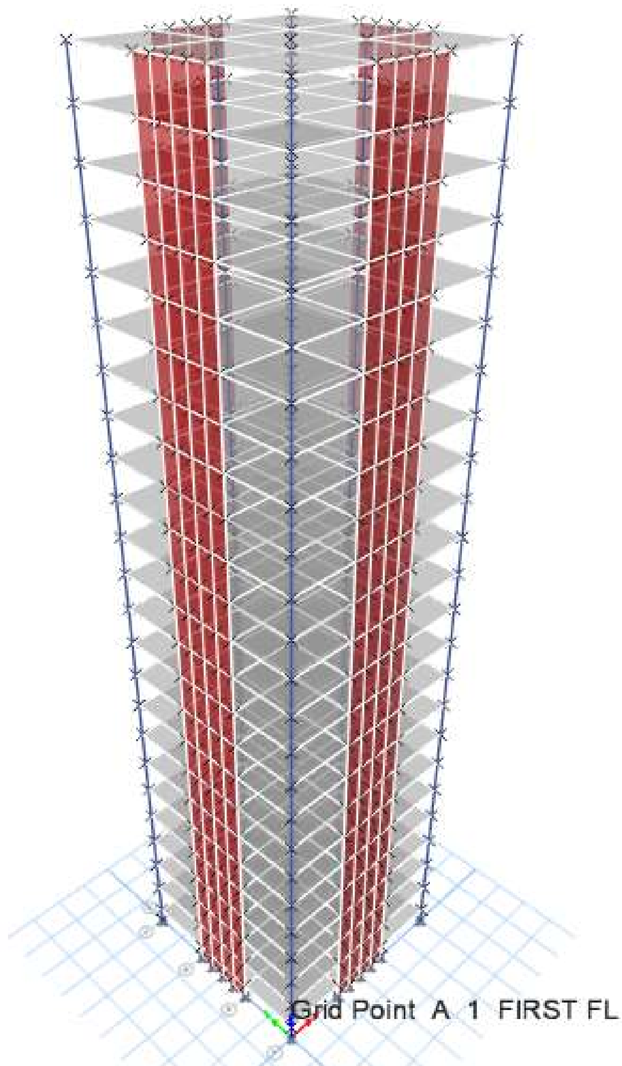


Figure 33: 3D view of G+22 model without water tank

TIME PERIOD

Time period = $0.075\ h^{0.75}$
$= 0.075\ (77.4)^{0.75}$

Time period = 1.9571 Seconds

Tank Dimensions :

Length = 3m

Width = 6m

Height = 3m

Liquid Mass = 50kN

Water pressure on wall = H x Density of water
= 3m x 50kN/m^3
= 150 kN/m^2

Calculation for 50 thousand liter water tank :

Capacity of tank = 50000 liter

Tank Area = 3m x 6m = 18m^2

So, 50000 liter = 500kN

Water load at bottom = 500/18 = 27.77kN/m

When water load is Half = 27.77/2
=13.885kN/m^2

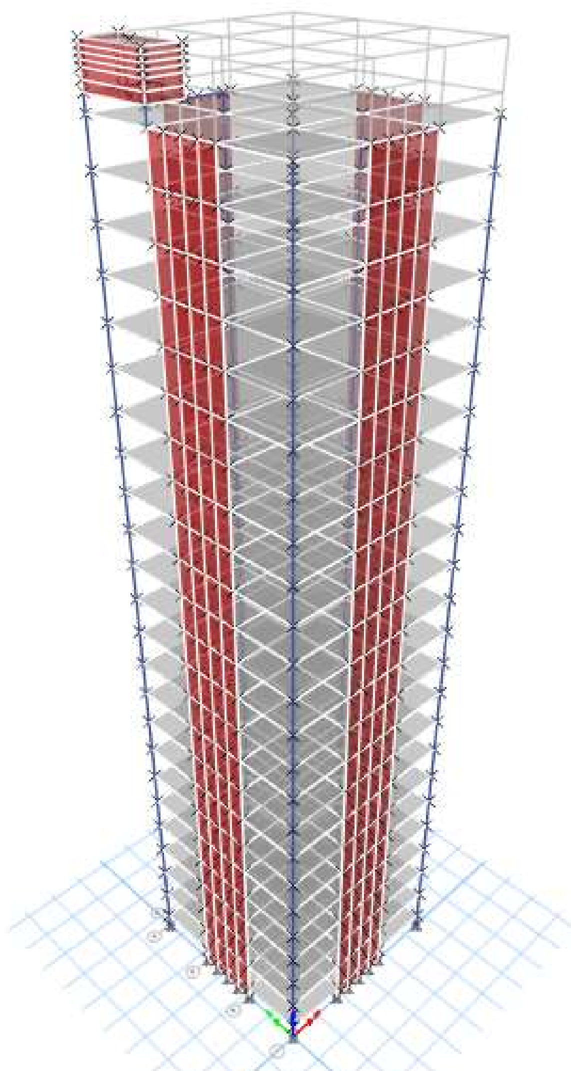


Figure 34: 3D view of G+22 model with tank of Empty, filled & Half water Depth

Analysis of G+22 model without Water tank & With Water tank using Time history analysis

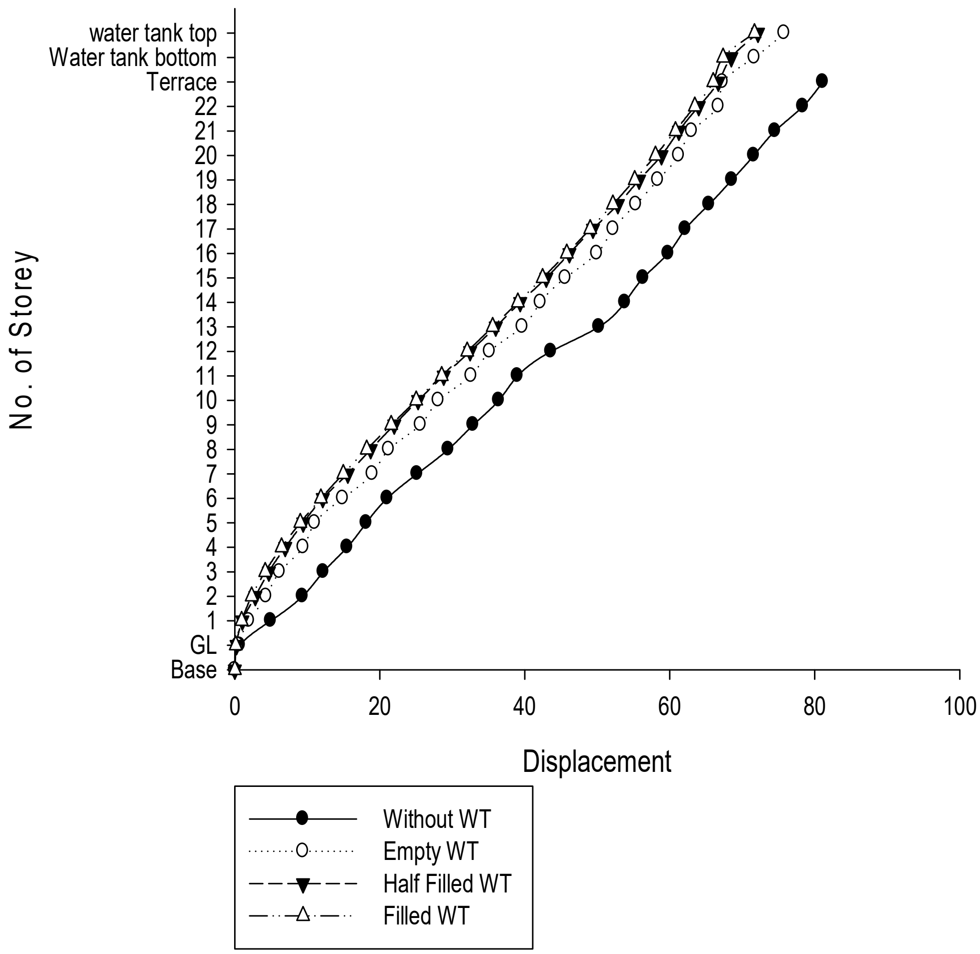


Figure 35: Maximum displacement for G+22 in the direction of X for EQX

No. of Storey	Without WT	Empty WT	Half filled WT	Filled WT
Base	0	0	0	0
GL	0.685	0.476	0.246	0.137
1	4.959	1.953	1.04	0.952
2	9.353	4.335	2.835	2.332
3	12.23	6.195	4.695	4.188
4	15.513	9.455	6.955	6.443
5	18.135	11.047	9.447	9.029
6	21.035	14.911	12.14	11.887
7	25.16	18.994	15.594	14.961
8	29.461	21.247	18.748	18.205
9	32.896	25.628	21.998	21.575
10	36.425	28.096	25.297	25.031
11	39.013	32.616	28.817	28.539
12	43.627	35.156	32.457	32.064
13	50.237	39.685	35.996	35.579
14	53.817	42.177	39.378	39.055
15	56.344	45.608	42.96	42.47
16	59.796	49.958	46.159	45.802
17	62.158	52.209	49.411	49.034
18	65.417	55.349	52.851	52.155
19	68.565	58.369	55.771	55.156
20	71.601	61.267	58.869	58.033
21	74.527	63.047	61.249	60.792
22	78.362	66.722	63.994	63.447
Terrace	81.103	67.295	66.698	66.001
Water tank bottom		71.685	68.487	67.353
water tank top		75.797	72.179	71.679

Table 21: Maximum Displacement values of G+22 structure for different stories in the direction of X for EQX (In MM)

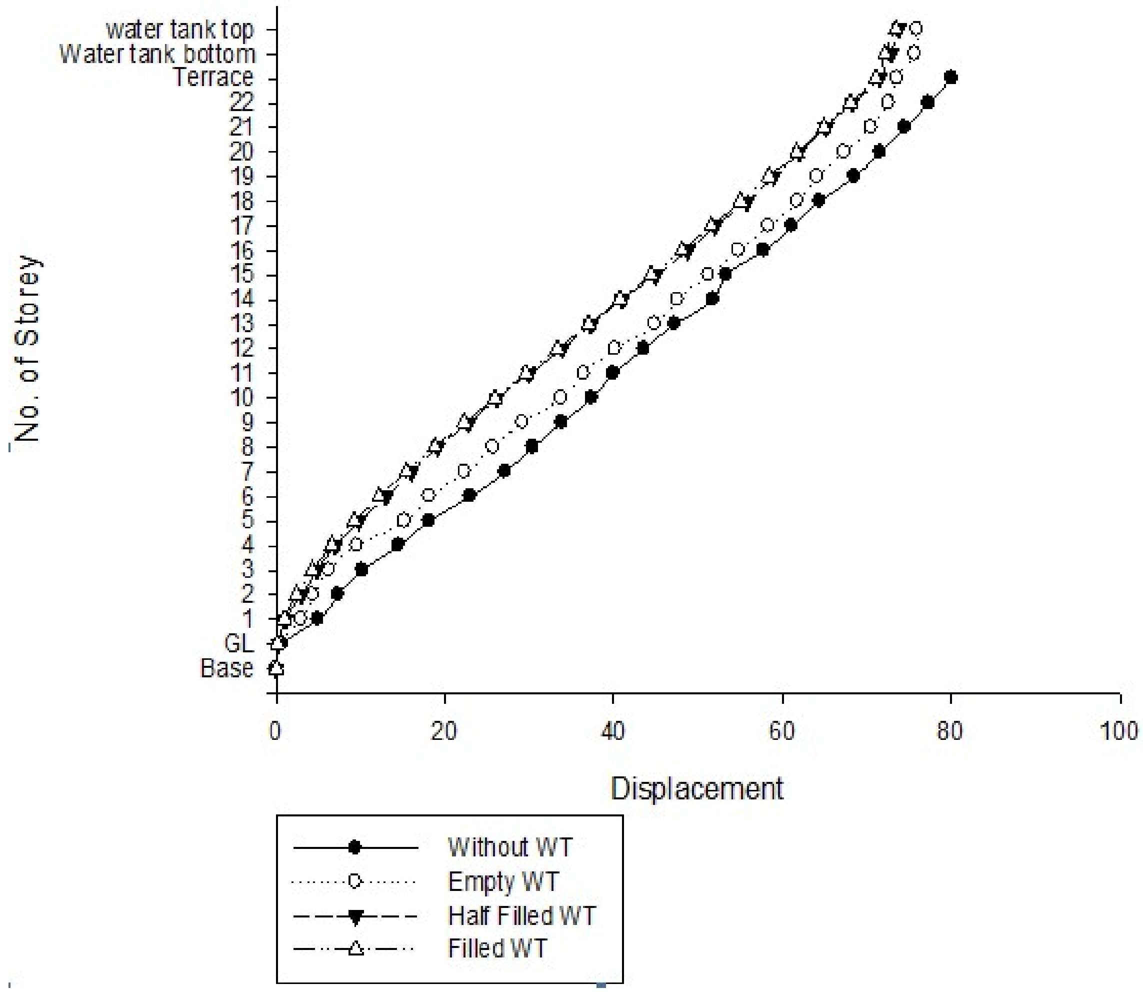


Figure 36: Maximum displacement for G+22 in the direction of Y for EQY

No. of Storey	Without WT	Empty WT	Half filled WT	Filled WT
Base	0	0	0	0
GL	0.689	0.479	0.271	0.138
1	4.959	2.967	1.167	0.968
2	7.353	4.374	2.987	2.378
3	10.23	6.272	4.872	4.28
4	14.513	9.583	6.983	6.596
5	18.135	15.24	9.84	9.26
6	23.035	18.182	12.98	12.21
7	27.159	22.356	15.995	15.394
8	30.46	25.715	19.14	18.764
9	33.895	29.215	22.815	22.277
10	37.424	33.818	26.178	25.894
11	40.012	36.489	29.988	29.581
12	43.625	40.194	33.893	33.305
13	47.235	44.907	37.324	37.037
14	51.815	47.6	40.998	40.752
15	53.341	51.251	44.949	44.427
16	57.794	54.841	48.775	48.044
17	61.155	58.354	51.995	51.587
18	64.414	61.78	55.778	55.044
19	68.562	64.113	58.975	58.412
20	71.597	67.352	61.98	61.69
21	74.524	70.505	65.112	64.886
22	77.358	72.59	68.286	68.018
Terrace	80.099	73.609	71.505	71.089
Water tank bottom		75.677	72.873	72.175
water tank top		75.949	73.844	73.442

Table 22: Maximum Displacement values of G+22 structure for different stories in the direction of Y for EQY (In MM)

Results

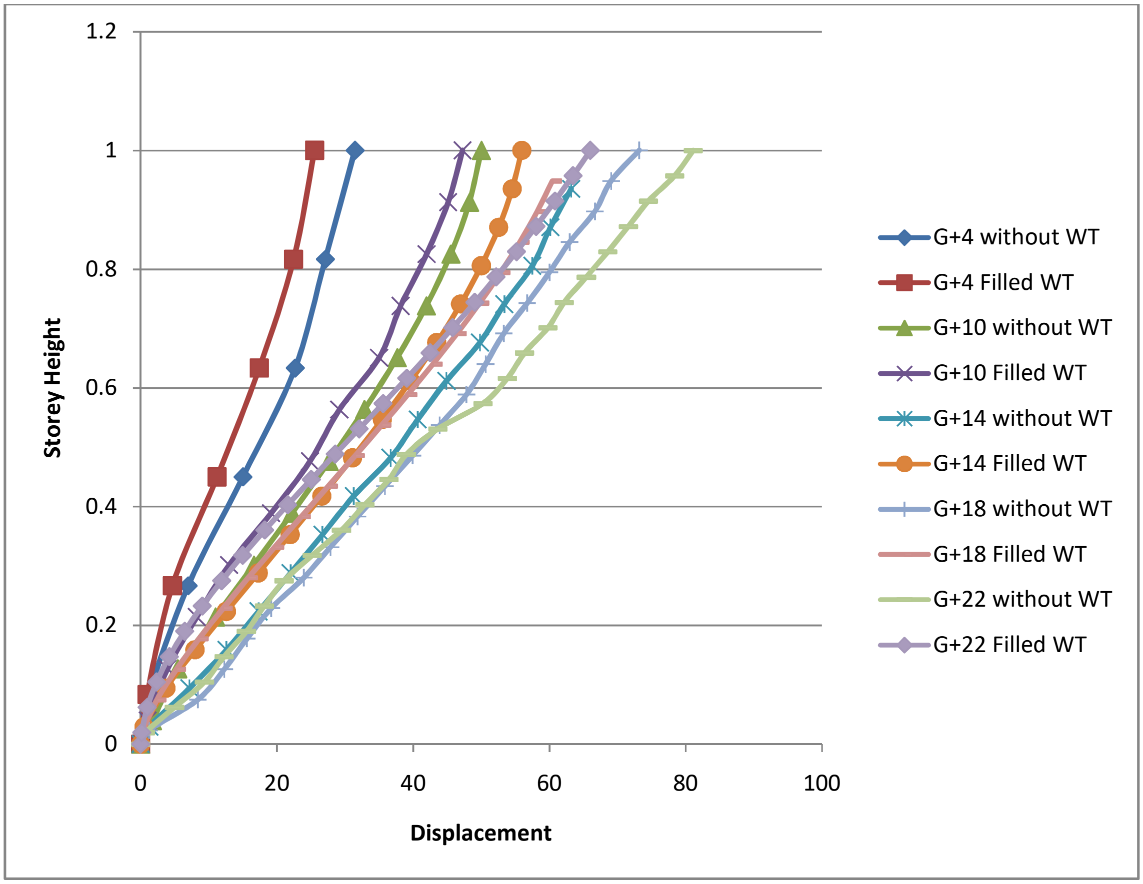


Figure 37: Comparison of Displacements of different Buildings at different Storey Heights in the direction of X for EQX

1	G+4			G+10			G+14			G+18			G+22		
2	Storey Height	Without WT	Filled WT	Storey Height	Without WT	Filled WT	Storey Height	Without WT	Filled WT	Storey Height	Without WT	Filled WT	Storey Height	Without WT	Filled WT
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0.083333333	1.187	0.948	0.03968254	1.743	1.004	0.029411765	1.283	0.484	0.023364	1.228	0.327	0.01938	0.685	0.137
5	0.266666667	6.972	4.654	0.126984127	5.44	3.935	0.094117647	7.17	3.696	0.074766	8.37	2.361	0.062016	4.959	0.952
6	0.45	15.002	11.193	0.214285714	10.977	8.229	0.158823529	12.59	7.969	0.126168	12.277	5.25	0.104651	9.353	2.332
7	0.633333333	22.673	17.39	0.301587302	16.613	12.975	0.223529412	17.298	12.559	0.17757	15.595	8.541	0.147287	12.23	4.188
8	0.816666667	27.1	22.43	0.388888889	22.202	19.135	0.288235294	22.016	17.243	0.228972	19.174	12.083	0.189922	15.513	6.443
9	1	31.452	25.498	0.476190476	27.645	24.854	0.352941176	26.688	21.931	0.280374	23.939	15.801	0.232558	18.135	9.029
10				0.563492063	32.834	29.162	0.417647059	31.261	26.562	0.331776	27.838	19.643	0.275194	21.035	11.887
11				0.650793651	37.642	34.997	0.482352941	36.681	31.09	0.383178	31.825	23.563	0.317829	25.16	14.961
12				0.738095238	41.924	38.154	0.547058824	40.681	35.456	0.434579	35.857	27.519	0.360465	29.461	18.205
13				0.825396825	45.517	41.974	0.611764706	44.885	39.6	0.485981	39.894	31.47	0.403101	32.896	21.575
14				0.912698413	48.248	45.124	0.676470588	49.807	43.454	0.537383	43.894	35.374	0.445736	36.425	25.031
15				1	49.992	47.246	0.741176471	53.375	46.947	0.588785	47.819	39.192	0.488372	39.013	28.539
16							0.805882353	57.51	50.002	0.640187	50.628	42.886	0.531008	43.627	32.064
17							0.870588235	60.137	52.542	0.691589	53.283	46.416	0.573643	50.237	35.579
18							0.935294118	63.191	54.511	0.742991	56.748	49.746	0.616279	53.817	39.055
19							1	66.68	55.93	0.794393	59.987	52.839	0.658915	56.344	42.47
20										0.845794	62.966	55.664	0.70155	59.796	45.802
21										0.897196	66.659	58.194	0.744186	62.158	49.034
22										0.948598	69.046	60.413	0.786822	65.417	52.155
23										1	73.157	62.362	0.829457	68.565	55.156
24													0.872093	71.601	58.033
25													0.914729	74.527	60.792
26													0.957364	78.362	63.447
27													1	81.103	66.001

Table 23: Data of Displacements of different Buildings at different Storey Heights in the direction of X for EQX

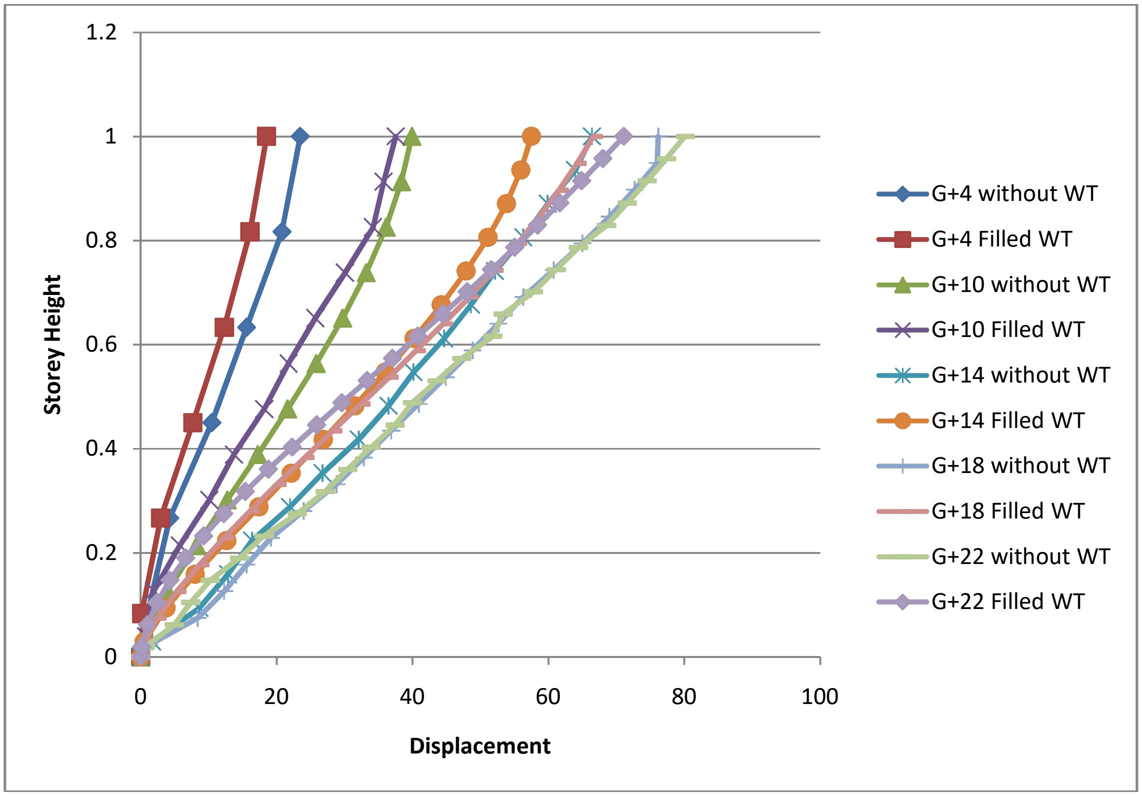


Figure 38: Comparison of Displacements of different Buildings at different Storey Heights in the direction of Y for EQY

1	G+4			G+10			G+14			G+18			G+22		
2	Storey Height	Without WT	Filled WT	Storey Height	Without WT	Filled WT	Storey Height	Without WT	Filled WT	Storey Height	Without WT	Filled WT	Storey Height	Without WT	Filled WT
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0.083333333	1.029	0.138	0.03968254	1.013	0.752	0.029411765	1.659	0.485	0.023364	1.235	0.329	0.01938	0.689	0.138
5	0.266666667	4.246	2.927	0.126984127	3.918	1.932	0.094117647	8.642	3.711	0.074766	8.37	2.383	0.062016	4.959	0.968
6	0.45	10.458	7.647	0.214285714	8.215	5.753	0.158823529	12.85	8.011	0.126168	12.277	5.312	0.104651	7.353	2.378
7	0.633333333	15.569	12.283	0.301587302	12.713	10.084	0.223529412	16.369	12.643	0.17757	15.595	8.663	0.147287	10.23	4.28
8	0.816666667	20.759	16.08	0.388888889	17.21	13.725	0.288235294	21.97	17.382	0.228972	19.174	12.286	0.189922	14.513	6.596
9	1	23.452	18.506	0.476190476	21.604	18.172	0.352941176	26.752	22.14	0.280374	23.939	16.107	0.232558	18.135	9.26
10				0.563492063	25.8	21.731	0.417647059	32.078	26.855	0.331776	28.838	20.072	0.275194	23.035	12.21
11				0.650793651	29.693	25.697	0.482352941	36.462	31.48	0.383178	32.825	24.138	0.317829	27.159	15.394
12				0.738095238	33.168	30.054	0.547058824	40.112	35.958	0.434579	36.857	28.261	0.360465	30.46	18.764
13				0.825396825	36.097	34.173	0.611764706	44.648	40.227	0.485981	40.894	32.401	0.403101	33.895	22.277
14				0.912698413	38.355	35.722	0.676470588	48.565	44.221	0.537383	44.894	36.518	0.445736	37.424	25.894
15				1	39.886	37.505	0.741176471	52.134	47.867	0.588785	48.819	40.574	0.488372	40.012	29.581
16							0.805882353	56.272	51.087	0.640187	52.628	44.529	0.531008	43.625	33.305
17							0.870588235	59.894	53.802	0.691589	56.283	48.347	0.573643	47.235	37.037
18							0.935294118	63.928	55.94	0.742991	60.748	51.993	0.616279	51.815	40.752
19							1	66.376	57.481	0.794393	64.987	55.431	0.658915	53.341	44.427
20										0.845794	68.966	58.631	0.70155	57.794	48.044
21										0.897196	72.659	61.568	0.744186	61.155	51.587
22										0.948598	76.046	64.217	0.786822	64.414	55.044
23										1	76.157	66.604	0.829457	68.562	58.412
24													0.872093	71.597	61.69
25													0.914729	74.524	64.886
26													0.957364	77.358	68.018
27													1	80.099	71.089

Table 24: Data of Displacements of different Buildings at different Storey Heights in the direction of Y for EQY

CONCLUSION

1. It was found that water tanks can be used effectively as passive TMDs to monitor the vibrations of the earthquake system.

2. From this study it was found that TLD can be used successfully to monitor the structure 's response. Water tank with full tank condition can exhibit tuned mass damper properties as opposed to empty tank condition.

3. TLD activity with different depths of the water tank is more effective in minimizing the structural vibration.

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